Charles River Basin Nutrient (Phosphorus) TMDLs, Phosphorus Load Export Rates and BMP Performance

The following topics are addressed in this Attachment to the Fact Sheet:

(A)The Charles River TMDLs and Phosphorus Reduction Requirement as Water-Quality Based Controls;
(B) Background Information on the Charles River Watershed, Massachusetts;
(C) Overview of Massachusetts Surface Water Quality Standards that Relate to Water Quality Impairments Caused by Excessive phosphorus loading;
(D) Causal Relationship between Phosphorus and Aquatic Plant/Algal Growth in the Charles River;
(E) Water Quality Assessments of the Charles River relating to non-attainment of Massachusetts water quality standards and excessive phosphorus loading;
(F) Stormwater Phosphorus Load and Watershed Imperviousness;
(G) Charles River TMDL Water Quality Based Analyses and Phosphorus Load Reduction Requirements for Stormwater Discharges;
(H) Phosphorus Control Plan Requirements and Cost
(I)Non Structural stormwater Phosphorus BMPs
(J)Structural stormwater Phosphorus BMPs
(K) Phosphorus Loading Associated with New Development

<u>(A) The Charles River TMDLs and Phosphorus Reduction Requirement as Water-Quality Based Controls</u>

A TMDL for a given pollutant and waterbody is composed of the sum of individual WLAs for NPDES-regulated point sources--such as wastewater treatment facilities, combined sewer overflows, and certain storm water discharges through point sources-- and load allocations (LAs) for nonpoint sources, non-regulated point sources and natural background levels. In addition, a TMDL includes a margin of safety (MOS) to account for uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody.

$$TMDL = WLA + LA + MOS$$

In TMDL development, allowable loadings from all pollutant sources must sum to no more than the loading capacity of the receiving water. The allowable loadings in the TMDLcan be used asthe basis for establishing water quality-based controls applied through the NPDES permitting process. As indicated above EPA has approved two TMDLs related to phosphorus discharges to the Charles River (Lower Charles TMDL - October 17, 2007 and the Upper/Middle Charles TMDL - June 10, 2011).

The Draft Permit requires community specific reductions in annual stormwater phosphorus load for the Charles River watershed area within: a) the community's boundaries; or b) the regulated MS4 area. The community specific annual phosphorus load reduction requirements are based on using the land use based (Upper/Middle Charles TMDL) and/or the watershed based (Lower Charles TMDL) percent reduction rates taken directly from the WLAs in the TMDL analyses. The use of these reduction rates to calculate the community specific phosphorus load reduction requirement is discussed in greater detail below in Section G of this Part.

(B) Background Information on the Charles River Watershed

The entire Charles River drains a watershed area of 310 square miles (MAEOEA, 2008). The Upper Charles River upstream of the Watertown Dam drains an area of 268 square miles, while the Lower Charles River downstream from the Watertown Dam to Boston Harbor drains an additional 42 square miles. There is also a combined sewer drainage area near the downstream end of the Lower Charles River.

The Charles River Watershed, includes in whole or in part, 36 communities, shown in Figure 1, below.

Figure 1: Charles River Watershed, Eastern Massachusetts

As indicated above, the portion of the Charles River downstream of the Watertown Dam is referred to as the Lower Charles River. The Lower Charles River is one of the most historically and culturally significant rivers in the United States. As indicated in Figure 2, the river and its adjacent parkland are used by the public for recreation, including sail boarding, sailing, rowing, running, and other water and non-water related recreation by an estimated 20,000 people per day (Breault et. al 2002).

Figure 2: Sailboat racing on the Lower Charles River (Walshrogalski, 2008)

In 1995 EPA New England launched the Clean Charles initiative aimed at making the Lower Charles River fishable and swimmable, the designated uses for the Charles River as a Class B surface water, and —the goals of the CWA. At that time, the Lower Charles River was meeting swimming standards for bacteria 19% of the time and boating standards for bacteria 39% of the time based on Charles River Watershed Association data. In 2012, the Lower Charles River was meeting the bacteria standard for swimming 67% of the time and the bacteria standard for boating 87% of the time based on the same sampling program. These dramatic improvements in reducing bacterial contamination resulted from the investment of hundreds of millions of dollars by the Massachusetts Water Resources Authority (MWRA), EPA, the Massachusetts Department of Environmental Protection (MassDEP), municipalities in the Lower Charles River watershed and numerous other private and public entities.

While vast strides have been made in reducing bacterial contamination in the river, scientific study indicates that the river's water quality continues to be impaired as a result of cultural eutrophication (Massachusetts Department of Environmental Protection , 2007) (Massachusetts Department of Environmental Protection, 2011). Cultural eutrophication is the process by which phosphorus and other nutrient discharges from human activities cause the growth of excessive plant life, including algae, that impairs water quality. Cultural eutrophication causes violations of water quality standards, including the impairment of the designated uses of the Charles. Establishment of the Charles River phosphorus TMDLs and development of the phosphorus reduction requirements in the Draft Permit are intended to address those violations and impairments.

(C) Overview of Massachusetts Surface Water Quality Standards that Relate to Water Quality Impairments Caused by Excessive phosphorus loading

A summary of the Massachusetts water quality criteria applicable to the Charles River and phosphorus loading are presented in Table 1. Massachusetts has not established numeric criteria for phosphorus, only narrative nutrient criteria. However, excessive phosphorus in a waterbody can cause a violation of other numeric criteria, such as those for pH and dissolved oxygen (DO).

Pollutant	Criteria	Source
DO	Shall not be less than 5.0 mg/L in warm water fisheries unless background conditions are lower; natural seasonal and daily variations above these levels shall be maintained; and levels shall not be below 60 percent of saturation in warm water fisheries due to a discharge.	314 CMR: 4.05: Classes and Criteria (3)(b) 1
pH	Shall be in the range of 6.5 - 8.3 standard units and not more than 0.5 units outside of the background range. There shall be no change from background conditions that would impair any use assigned to this Class.	314 CMR: 4.05: Classes and Criteria (3)(b) 3
Solids	These waters shall be free from floating, suspended, and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.	314 CMR: 4.05: Classes and Criteria (3)(b) 5.
Color and Turbidity	These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class.	314 CMR: 4.05: Classes and Criteria (3)(b) 6
Aesthetics	All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.	314 CMR: 4.05: Classes and Criteria (5)(a)
Nutrients	Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department.	314 CMR: 4.05: Classes and Criteria (5)(c)

Table 1: Applicable Massachusetts Surface Water Quality Criteria

(D) Causal Relationships between Phosphorus and Aquatic Plant and Algal Growth in the Charles River

The causal relationship between excessive phosphorus loads and water quality impairments is well understood and is covered extensively in research literature. Analyses of water quality data collected from the Charles River indicate that phosphorus is the key nutrient that controls the amount of algal and aquatic plant growth during the middle to later summer period in the Charles River when recreational use of the river peaks.

During this period, excessive phosphorus levels in the Charles River coincides with water quality and climatic conditions, including warm ambient temperatures, high sunlight intensity, and lower river flows (which increase water residence times) that are optimal for algal and aquatic plant growth. During these optimal growth conditions, excessive phosphorus levels in the Charles River cause dramatic increases in algae and plant biomass, which in turn cause and contribute to non-attainment of water quality standards (Massachusetts Department of Environmental Protection , 2007) (EPA data 1998-2007).

The Charles River TMDL analyses indicate that phosphorus is discharged to the Charles River and its tributaries from a variety of sources. These sources include effluent from wastewater treatment facilities (WWTFs), stormwater runoff from developed land areas, combined sewer overflow (CSO) discharges (only to the Lower Charles), illicit sanitary sewage discharges, natural runoff from undeveloped lands such as forested areas, and groundwater discharges that sustain baseflow in the Charles River system.

The Charles River system is low gradient and includes numerous impounded sections created by the presence of dams. These physical characteristics are estimated to substantially attenuate phosphorus loads within the system such that phosphorus loads discharged at any time during the year in both wet and dry conditions have the potential to contribute to excessive algae and plant growth during the critical growing season.

<u>(E) Water Quality Assessments of the Charles River relating to non-attainment of Massachusetts water quality standards and excessive phosphorus loading</u>

Based on water quality data available for the Charles River and applicable State water quality standards for a Class B surface water, MassDEP included many segments of the Charles River on the State's 2002, 2004, 2006, 2008, 2010 and 2012 Section 303(d) lists for several pollutants and identified conditions that caused violations of those standards. Among these 303(d) listed pollutants and conditions are several related to excessive phosphorus loading:

- Nutrients
- Organic enrichment/Low DO
- Taste, odor, and color
- Noxious aquatic plants
- Turbidity

MassDEP's water quality assessment analyses also indicate that phosphorus in stormwater runoff is a significant cause of water quality impairments in almost all of the Charles River segments. Table 3 summarizes the assessment results relating to phosphorus, as provided by MassDEP's assessment report, for all of the Charles River segments. All segments of the Charles River, excepting the headwater segment are impaired, at least in part, because of elevated phosphorus, excessive aquatic plant growth and/or algae. In addition to these river segment assessments, MassDEP has determined that Milford Pond is impaired due to excessive aquatic plant growth and Populatic Pond is impaired due to excessive algal growth. These ponds are impoundments in the mainstream of the Charles River. Figure 3 provides pictorial examples of degraded water quality conditions related to excessive phosphorus at numerous locations throughout the Charles River watershed.

Charles River Segment No.	Charles River Main stem Segment Description	Use impairment related to phosphorus	Suspected source contributing to phosphorus-related impairment
(MA72-01)	Outlet of Echo Lake to just upstream of Milford Pond, 2.5 miles, Hopkinton/Milford	None identified	None identified
(MA72-33)	Outlet of Milford Pond to the Milford WWTF discharge, 2.0 miles, Milford/Hopedale	Aquatic life	Urban runoff/storm water
(MA72-03)	Milford WWTF discharge to Outlet of Box Pond, 3.4 miles, Hopedale/Bellingham	Aquatic life, primary contact, secondary contact, and aesthetics	Municipal WWTF, urban runoff/storm water
(MA72-04)	Outlet Box Pond to inlet to Populatic Pond, 11.5 miles, Bellingham, Norfolk/Medway	Aquatic life (7.5 miles)	Municipal WWTF in upstream segment, urban runoff/storm water
(MA72-05)	Outlet of Populatic Pond to South Natick Dam, 18.1 miles, Norfolk/Medway/Natick	Aquatic life, primary contact, secondary contact, and aesthetics	Municipal WWTF, urban runoff/storm water, nonpoint sources
(MA72-06)	South Natick Dam to the Chestnut St. Needham, 8.4 miles, Natick/Needham	Aquatic life, primary contact, secondary contact, and aesthetics	Municipal WWTFs in upstream segments, urban runoff/storm water, nonpoint sources
(MA72-07)	Chestnut St. Needham to Watertown Dam, 24.8 miles, Needham/Watertown	Aquatic life, primary contact, secondary contact, and aesthetics	Municipal WWTFs in upstream segments, urban runoff/storm water, nonpoint sources
(MA72-36)	Watertown Dam to Boston University Bridge, 6.1 miles, Watertown/Boston/Cambridge	Aquatic life, primary contact, secondary contact, and aesthetics	Municipal WWTFs in upstream segments, urban runoff/storm water
(MA72-38)	Boston University Bridge to New Charles River Dam, 3.1 miles, Boston/Cambridge	Aquatic life, primary contact, secondary contact, and aesthetics	Municipal WWTFs in upstream segments, urban runoff/storm water

Table 2: Summary of MassDEP water quality assessments for the main stem of Charles River related to phosphorus (excerpted from the Charles River Watershed 2002-2006 Water Quality Assessment Report, MassDEP, April, 2008)

As indicated in the listing of suspected sources in Table 2 (column 4), municipal wastewater treatment facilities (WWTFs) are identified as sources to many of the segments. Presently, through continued re-issuances of NPDES permits with phosphorus effluent limitations, WWTFs have reduced their phosphorus load to the Charles River by well over 90% (EPA, 2011).

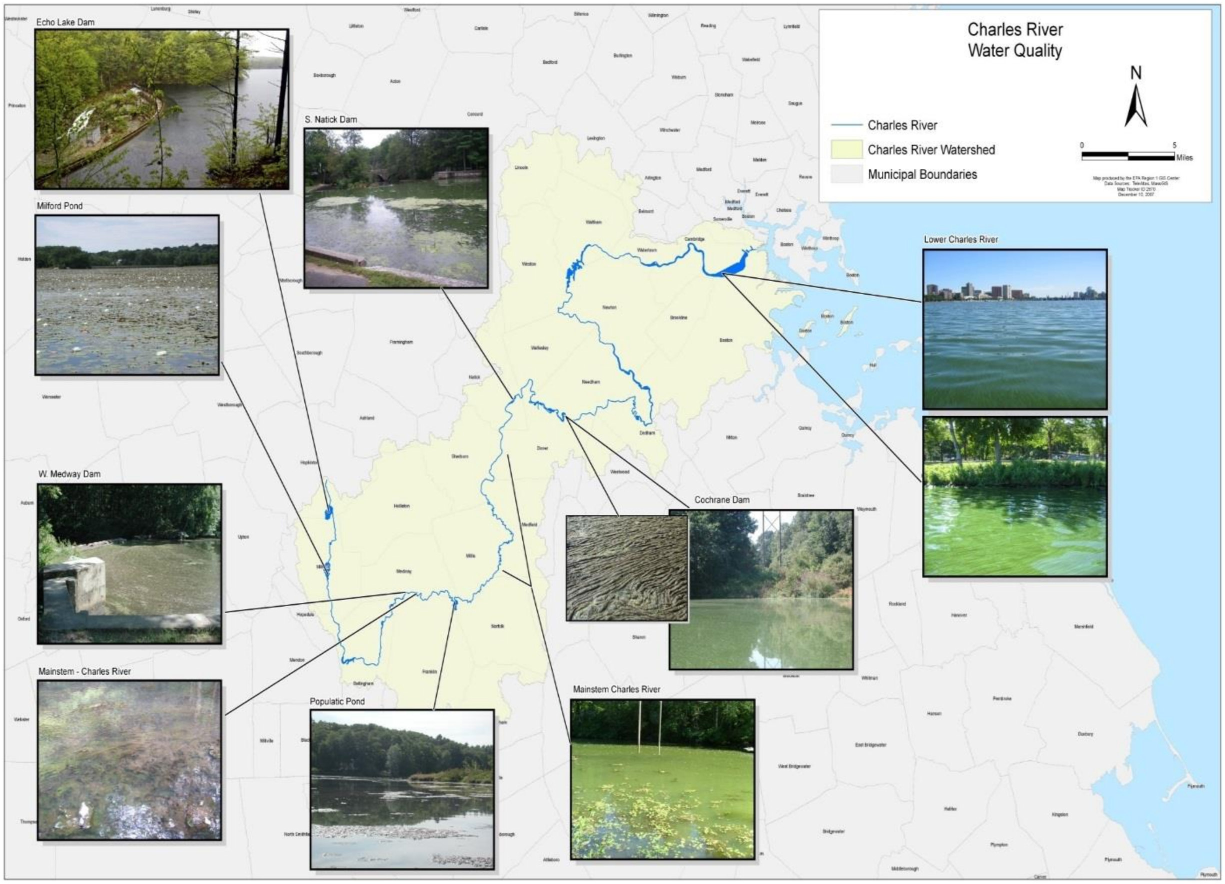

Figure 3: Degraded water quality conditions related to excessive phosphorus levels in the Charles River Watershed

(F) Stormwater Phosphorus loading and Watershed Imperviousness

The urban and suburban landscape contains a variety of phosphorus sources. These include dust and dirt, atmospheric deposition, decaying organic matter (such as leaf litter and grass clippings), fertilizers, exhaust from internal combustion engines, detergents, and pet waste (Center for Watershed Protection (CWP)), 2007 and Shaver et al. 2007). Intensive uses, including high traffic volume (particularly of trucks and busses), increase pollutant loading to the impervious surfaces. Impervious surfaces collect phosphorus deposited on them from these sources.

Numerous scientific studies document that impervious cover both increases the volume of rainfall that becomes runoff and amplifies the loads of pollutants flowing to surface waters (Schuleler, 1987; CWP, 2007; Shaver et al., 2007; Pitt et al., 2004; Horner et al., 1994). There are several reasons for this: 1) rain falling on impervious cover runs off without infiltrating into the ground, thus creating a higher volume of runoff per unit area; 2) unlike pervious areas that can trap and filter pollutants through soils and vegetation, impervious areas allow greater amounts of pollutants to be carried away by runoff; and 3) pollutants such as phosphorus on impervious surfaces are particularly susceptible to transport by runoff because of their tendency to adhere to very small particles, which are easily washed off hard surfaces by rainfall. These small particles (< 100 microns) account for much of the phosphorus storm water load that discharges to receiving waters. These three factors operating simultaneously dramatically increase phosphorus loadings from impervious surfaces.

In the CRW specifically, the extent of imperviousness differs by land use. As land has been developed from its natural state, impervious surfaces, such as roadways, parking lots and roof tops, have proliferated. Table 3 illustrates the relationship between several common land use groups, drainage area imperviousness and literature reported composite phosphorus load export rates (PLERs). PLERs are measures of the annual phosphorus load in stormwater discharges and are expressed in terms of kilograms per hectare per year (kg/ha/yr). Composite PLERs represent the combined amount of phosphorus load generated by both impervious cover and pervious cover for a given land use group.

Table 3 also provides calculated PLERs based on using the Simple Method (Schueler, 1987)(4th and 6th columns) for varying percent imperviousness reported by land use in the literature and based on a land cover analysis of the CRW (3rd and 5th columns, respectively). The Simple Method has been widely used in the stormwater management field to estimate annual pollutant loadings and takes into account annual rainfall, impervious cover and stormwater phosphorus strength. These results are provided to further illustrate how estimates of PLERs are expected to vary according to percent imperviousness. Overall, this information is intended to convey the general relationship that exists between imperviousness, land use and PLERs.

Land Cover	Literature reported phosphorus load export rate kg/ha/yr (source)	Ranges in percent impervious values typical for various land uses (Schueler 1987)	Range of annual phosphorus load export rates developed using the Simple Method, Schueler,1987 (3) kg/ha/yr	Charles River watershed percent imperviousness by land use (MassGIS, 2005)	Annual phosphorus load export rates for Charles River using the Simple Method, Schueler,1987 (3) kg/ha/yr
Commercial	1.679 (1)	60-90%	1.17 - 2.57	62	1.30
Industrial	1.455 (1)	60-90%	1.17 - 2.57	71	1.45
High Density Residential	1.12 (1)	35-60%	0.80 - 1.76	42	1.20
Medium Density Residential	0.56 (1)	20-35%	0.59 - 1.09	29	0.62
Low Density Residential	0.30 (2)	5-20%	0.25 – 0.53	23	0.41

Table 3: Annual land use based phosphorus load export rates (PLERs) reported in literature and based on calculations using the Simple Method

1. Shaver, E., Horner R., Skupien J., May C., and Ridley G. 2007 Fundamentals of urban runoff management: technical and institutional issues. Prepared by the North American Lake Management Society, Madison, WI, in cooperation with the U.S. Environmental Protection Agency.
2. Mattson, Mark D. and Russell A. Isaac. 1999. Calibration of phosphorus export coefficients for Total Maximum Daily loads of Massachusetts's lakes. Lake Reservoir. Management, 15:209-219.
3. Schueler, Thomas R. July 1987. Controlling urban runoff; a practical manual for planning and designing urban BMPs. For this Table stormwater TP concentrations of 0.26 mg/L was used residential and open space uses, 0.20 mg/l for commercial & industrial uses, 0.5 mg/L for agriculture and 0.15 mg/L for forested.

In addition to illustrating the relationship between annual phosphorus loads and the degree of imperviousness in developed lands, the use of PLERs offers an equitable accounting system for the CRW and other phosphorus TMDL watersheds. PLERs are used in the Massachusetts Small MS4 permit for the following purposes:

1. Characterization of stormwater phosphorus loads from various land use groups based on cover type (i.e., impervious or pervious) (described n Section G of this Part);
2. Calculation of baseline stormwater phosphorus loads and associated phosphorus load reduction requirements for CRW permittees based on watershed characteristics specific to each permittee's watershed area (described in Section G of this Part);
3. Part of the methodology for permittees to calculate the change in stormwater phosphorus loads associated with future new development, redevelopment or changes in land use (described below in Section H of this Part); and
4. Part of the methodologies for permittees to calculate stormwater phosphorus load reductions associated with planned and implemented non-structural and structural BMPs (described below in Section J of this Part)

<u>(G) Charles River TMDL Waste load Allocations and Phosphorus Load Reduction Requirements for Stormwater Discharges</u>

Charles River TMDLs: The Phosphorus TMDL analyses for the Charles River watershed (CRW) quantified phosphorus loadings to the Charles River and through the use of extensive data and modeling analyses estimated the average annual phosphorus load the river could receive and still comply with Massachusetts Surface Water Quality Standards. Both TMDLs quantified total phosphorus loading to their respective river segments (9 miles for the Lower Charles and 70+ miles for the Upper/Middle Charles) based on detailed watershed source characterizations and accounting of WWTF and CSO discharges.

A common geographic point between the two TMDL analyses is the Watertown Dam, the boundary separating the Lower and the Upper/Middle Charles. At this location, both TMDLs quantified the average annual phosphorus load discharging to the Lower Charles River for the data rich five year period of 1998-2002. This common point allows for the two TMDL analyses to be used in combination to derive community specific phosphorus reduction requirements for the entire CRW based on the WLAs established in the TMDLs.

As required by TMDL regulations, both TMDLs specified WLAs for the WWTF and CSO discharges as well as for regulated stormwater discharges at levels that would result in attainment of water quality standards. For these two TMDL analyses, Massachusetts chose to assign all stormwater related discharges (regulated and currently non-regulated) WLAs. However, the two TMDLs differed in how the WLAs are expressed. The Lower Charles TMDL quantified loads by watershed area and specified WLA percent reductions by watershed area, while the Upper/Middle Charles TMDL quantified loads by land use grouping and applied varying percent reduction rates for land use groups that cover the watershed. Table 4presents the watershed based WLA percent reduction rates presented in the Lower Charles TMDL and Table 5presents the land use based WLA percent reduction rates specified in the Upper/Middle Charles TMDL.

The Lower Charles TMDL included an implementation plan which included an estimation of stormwater phosphorus load reductions needed from developed lands in the CRW in order to be consistent with the WLAs specified in the TMDL. Development of the estimation involved a multi-step process that included a land use cover analysis, the calculation of land use based phosphorus loads using measured CRW land use areas and representative land use based composite PLERs, and estimates of the reductions needed to be consistent with the TMDL specified reductions. The PLERs used in the Lower Charles TMDL implementation plan were derived from reported literature values. The calculated phosphorus load using the land use specific PLERs was compared to the measured average annual phosphorus load from the TMDL and found to be in close agreement (~1%). Consequently, it was concluded that use of the PLERs was a reasonable approach for estimating needed reductions for developed land stormwater sources. A final step in the process was to evaluate the technical feasibility of achieving the estimated reductions.

Watershed Source	Lower Charles TMDL WLA % Reduction Rate
Upstream Watershed at Watertown Dam	48%
Stony Brook Watershed	62%
Muddy River Watershed	62%
Laundry Brook Watershed	62%
Faneuil Brook Watershed	62%
Other Drainage Areas	62%

Table 4: WLA phosphorus load reduction rates applied to watershed areas in the Lower Charles TMDL

Land Use Group	Upper TMDL WLA % Reduction Rate
Commercial	65%
Industrial	65%
High Density Residential	65%
Medium Density Residential	65%
Low Density Residential	45%
Highway	65%
Open Space	35%
Agriculture	35%
Forest	0%

Table 5: WLA phosphorus load reduction rates applied to land use groups in the Upper/Middle Charles TMDL

Another commonality between the two TMDL analyses is that the recommended land use based reduction rates specified in the implementation plan for the Lower Charles TMDL are the same as the land use based WLA reduction rates established in the Upper/Middle Charles TMDL. Additionally, both TMDL Reports concluded that the substantial areas of forested lands within the watershed (38% of watershed area) are, for the most part, in a natural condition with relatively low phosphorus export rates. Consequently, it was determined that assigning load reductions for forested areas would not be reasonable or appropriate.

Calculated stormwater baseline loads: For this Draft Permit, a similar (although more comprehensive) approach as described above for the Lower Charles TMDL implementation plan was taken to estimate baseline stormwater phosphorus loads and reduction requirements for the CRW area in each community. Unlike the literature derived land use based PLERs used in the Lower Charles TMDL implementation plan, customized composite PLERs were calculated for each land use group in each community based on the community's watershed characteristics to calculate their baseline phosphorus load. Customized composite PLERs were calculated not only for CRW area within each community but also for the CRW land area owned by the Massachusetts Department of Transportation (MassDOT) and the Massachusetts Department of Conservation and Recreation (DCR) in the community. These two Massachusetts' Departments will be subject to CRW phosphorus reduction requirements similar to the municipal MS4s. These customized composite rates are calibrated to the total phosphorus load in the Charles River at the time of TMDL completion and therefore are only applicable to baseline phosphorus loading calculations and are not intended to be used to calculate phosphorus loading rates associated with new development within the town, see Part (k) of this Attachment for a detailed explanation.

The methodology used for calculating average annual baseline phosphorus loads and reductions for the CRW is intended to provide for a consistent and equitable accounting of phosphorus loads and reductions across the entire CRW. EPA has determined that it is necessary to provide a consistent accounting process for all CRW entities that will be subject to phosphorus reduction requirements to ensure that all entities do their fair share of stormwater phosphorus load reduction work and so that watershed-wide accounting can be tracked.

The following is an overview of the steps taken to calculate baseline stormwater phosphorus loads and phosphorus load reduction requirements for each CRW community, and for MassDOT's and DCR's land area within the CRW.

1. EPA compiled GIS data layers for the CRW to quantify the areal extent of several watershed attributes such as land use, hydrologic soil group, impervious area, urban area, and ownership by Mass DOT or DCR for each municipality within: 1) the entire Charles River Watershed; 2) the Upper Charles watershed upstream of Watertown Dam; and 3) the Lower Charles Watershed downstream of the Watertown Dam. Watershed attributes were determined for MassDOT and DCR properties within each CRW community so that baseline phosphorus loads and reductions could be appropriately apportioned to each municipality, MassDOT and DCR. Measured areas for the following watershed attributes were determined for each community within the CRW:
    a. Land Use Groups – (40 Mass GIS land use category IDs (2005) were first aggregated into the following 10 land use groups (see Attachment A for details)):
        i. Commercial;
        ii. Industrial;
        iii. High Density Residential;
        iv. Medium Density Residential;
        v. Low Density Residential;
        vi. Highway;
        vii. Open Land;
        viii. Forest;
        ix. Agriculture; and

x. Water

b. Total Impervious Area (TIA) by Land Use Group;
c. Hydrological Soil Groups (HSGs) by Land Use Group:
    i. HSG A;
    ii. HSG B;
    iii. HSG C;
    iv. HSG C/D;
    v. HSG D; and
    vi. Undefined
d. Urban Area as defined for MS4 permitting; and
e. Combined Sewer Area

2. EPA compiled critical information from the two Charles River watershed phosphorus TMDLs, *Final Total Maximum Daily Load for Nutrients in the Lower Charles River Basin, Massachusetts*. (MassDEP and EPA. 2007) http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/charlesp.pdf and *Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River, Massachusetts*(CRWA and NES for MassDEP, 2011) http://www.mass.gov/eea/docs/dep/water/resources/n-thru-y/ucharles.pdf Information taken directly from the TMDL reports includes:
    a. Waste Load Allocations (percent reductions);
    b. Quantification of water quality processes; and
    c. Quantification of phosphorus loads
3. EPA calculated Directly Connected Impervious Area (DCIA) percentages using total impervious area (TIA) and applicable Sutherland equations for each aggregate land use group in each community. DCIA percentages were calculated individually for the "Community" (henceforth defined as the community area within the CRW less the area of MassDOT and DCR properties); MassDOT; and DCR properties within the CRW. All combined sewer area was excluded from the analysis. The Sutherland equations applied to TIA for each of the land use groups is presented in Table 6 below;

Land Cover	Sutherland DCIA Equation Description	Sutherland Equation Used To Estimate Directly Connected Impervious Area (DCIA)
Commercial	Highly Connected	**$DCIA=0.4(TIA)^{1.2}$**
Industrial	Highly Connected	**$DCIA=0.4(TIA)^{1.2}$**
High Density Residential	Highly Connected	**$DCIA=0.4(TIA)^{1.2}$**
Medium Density Residential	Average	**$DCIA=0.1(TIA)^{1.5}$**
Low Density Residential	Average	**$DCIA=0.1(TIA)^{1.5}$**

Freeway	Average	**DCIA=0.1(TIA)$^{1.5}$**
Open Space	Average	**DCIA=0.1(TIA)$^{1.5}$**
Agriculture	Mostly Disconnected	**DCIA=0.01(TIA)$^{2.0}$**
Forest	Mostly Disconnected	**DCIA=0.01(TIA)$^{2.0}$**

Table 6: Sutherland equations used to estimate percent directly connected impervious area (DCIA) by land use group

4. EPA calculated average annual composite phosphorus load export rates (PLERs) for each aggregated land use group in each CRW community based on the distribution of impervious area and pervious area (as defined by HSG). Land use based composite PLERs were calculated for: 1) Community area; 2) MassDOT property; and 3) DCR property within the CRW.

   Land use based composite PLERs are calculated weighted averages using land use based distinct PLERs for DCIA and pervious areas (PA) by HSG and the distribution of impervious area and PA by HSG for each land use group within each community. The distinct PLERs used to calculate the base line load are provided in Table 7. The derivation of the distinct PLERs is described in a separate Memorandum (PLER Memo) dated May 24, 2014 with the subject heading*: Annual Average Phosphorus Load Export Rates (PLERs) for Use in Fulfilling phosphorus Load Reduction Requirements in EPA Region 1 stormwater Permits*. The distinct PLERs for DCIA were taken directly from the PLER Memo, while the distinct PLERs for PA by HSG were calculated as part of the process to estimate baseline phosphorus loads for the CRW. These distinct PA PLERs used to calculate baseline phosphorus loads differ from those presented in the PLER Memo as follows:
   - For baseline phosphorus loads, **developed land** PA PLERs (commercial, industrial, all residential, open land and highway) reflect phosphorus loading rates associated with phosphorus fertilizer use, while the distinct PA rates in the PLER Memo reflect lower phosphorus load conditions that is expected to occur following adoption of MA’s upcoming phosphorus free fertilizer regulations;
   - For baseline phosphorus loads, **forested** PA PLERs reflects both phosphorus loads from runoff and dry weather baseflow from the entire watershed, while the single distinct PA PLER for forested land in the PLER Memo represents primarily runoff. Additionally, distinct PA PLERs for forested land were calculated for each HSG to calculate baseline loads, while only one PA PLER is provided in the PLER Memo; and
   - For baseline phosphorus loads, **agriculture** PA PLERs were calculated for each PA HSG while only one average PA PLER is presented in the PLER Memo.

   In all cases for the CRW, PA PLERs for baseline phosphorus loads were calculated by multiplying hydrologic model derived average annual runoff yields by representative annual mean total phosphorus (TP) concentrations. Table 7 summarizes the annual mean TP concentrations used for calculating PA PLERs to estimate baseline phosphorus loads for the CRW. Land used based composite PLERs are calculated using the following equation:

Composite PLER = ((% DCIA/100) x DCIA PLER) + ((100 -%DCIA)/100) x PA-PLER)

Where: PA-PLER = the weighted average of PLERs for the HSGs based on the distribution of HSGs for the land use group.

As indicated, the amount of PA used in the above equation is equal to the total area minus the estimated DCIA area, which provides additional weight to the PA-PLER contribution (i.e., the difference between %TIA and %DCIA). This was done intentionally to reflect the likelihood that increased runoff from disconnected IA will result in increased runoff from the PA.

The calculated land use based composite PLERs for Community only area; MassDOT area; and DCR area in each municipality are presented in Table 9, Table 10 and Table 11, respectively. Table 12provides the overall calculated composite PLERs for the CRW by municipality ignoring property ownership. The watershed information used to calculate the composite PLERs including CRW areas by land use group, HSG, and TIA are presented in Attachment B to this fact sheet.

Phosphorus Source Category by Land Use	Land Surface Cover	Phosphorus load Export Rate, kg/ha/yr	Comments
Commercial (Com) and Industrial (Ind)	Directly connected impervious	2.0	Derived using a combination of the Lower Charles USGS Loads study and NSWQ dataset. This PLER is approximately 75% of the HDR PLER and reflects the difference in the distributions of stormwater TP EMCs between Commercial/Industrial and Residential.
	Pervious	See* DevPERV	
Multi-Family (MFR) and High-Density Residential (HDR)	Directly connected impervious	2.6	Largely based on loading information from Charles USGS loads, SWMM HRU modeling, and NSWQ data set
	Pervious	See* DevPERV	
Medium -Density Residential (MDR)	Directly connected impervious	2.2	Largely based on loading information from Charles USGS loads, SWMM HRU modeling, and NSWQ data set
	Pervious	See* DevPERV	
Low Density Residential (LDR) - "Rural"	Directly connected impervious	1.7	Derived in part from Mattson Issac, HRU modeling, lawn runoff TP quality information from Chesapeake Bay and subsequent modeling to estimate distinct PLER for DCIA to approximate literature reported composite rate 0.3 kg/ha/yr.
	Pervious	See* DevPERV	
Highway (HWY)	Directly connected impervious	1.5	Largely based on USGS highway runoff data, HRU modeling, information from Shaver et al and subsequent modeling to estimate distinct PLER for DCIA for literature reported composite rate 0.9 kg/ha/yr.
	Pervious	See* DevPERV	
Forest (For)	Directly connected impervious	1.7	Derived from Mattson & Issac and subsequent modeling to estimate PLER for DCIA that corresponds with the literature reported composite rate of 0.13 kg/ha/yr (Table 14)
	Pervious	**See ForPERV	
Open Land (Open)	Directly connected impervious	1.7	Derived in part from Mattson Issac, HRU modeling, lawn runoff TP quality information from Chesapeake Bay and subsequent modeling to estimate PLER for DCIA (Table 14) to approximate literature reported composite rate 0.3 kg/ha/yr.
	Pervious	See* DevPERV	
Agriculture (Ag)	Directly connected impervious	1.7	Derived from Budd, L.F. and D.W. Meals and subsequent modeling to estimate PLER for DCIA to approximate reported composite PLER of 0.5 kg/ha/yr.
	Pervious	***See AgPERV	
*Developed Land Pervious (DevPERV)- Hydrologic Soil Group A	Pervious	0.05	Derived from SWMM and P8 - Curve Number continuous simulation HRU modeling with assumed TP concentration of 0.3 mg/L for pervious runoff from developed lands. TP of 0.3 mg/L is based on TB-9 (CSN, 2011), and other PLER literature and assumes 50% of pervious developed lands receive phosphorus fertilization.
*Developed Land Pervious (DevPERV)- Hydrologic Soil Group B	Pervious	0.20	
*Developed Land Pervious (DevPERV) - Hydrologic Soil Group C	Pervious	0.40	

*Developed Land Pervious (DevPERV) - Hydrologic Soil Group C/D	Pervious	0.51	
*Developed Land Pervious (DevPERV) - Hydrologic Soil Group D	Pervious	0.61	
**Forested Land Pervious (ForPERV)-Hydrologic Soil Group A (includes baseflow)	Pervious	0.12	Derived from P8 - Curve Number continuous simulation HRU modeling with assumed TP concentration of 0.1 mg/L for pervious runoff from forested lands and baseflow with TP concentration of 0.015mg/l. Baseflow yields determined from USGS Lower Charles Loads study.
**Forested Land Pervious (ForPERV)-Hydrologic Soil Group B (includes baseflow)	Pervious	0.16	
**Forested Land Pervious (ForPERV)-Hydrologic Soil Group C (includes baseflow)	Pervious	0.21	
**Forested Land Pervious (ForPERV) - Hydrologic Soil Group C/D (includes baseflow)	Pervious	0.23	
*Forested Land Pervious (ForPERV) - Hydrologic Soil Group D (includes baseflow)	Pervious	0.26	
***Agriculture Land Pervious (AgPERV)- Hydrologic Soil Group A	Pervious	0.08	Derived from SWMM and P8 - Curve Number continuous simulation HRU modeling with assumed TP concentration of 0.5 mg/L for pervious runoff from developed lands. TP of 0.5 mg/L is based on PLER literature.
***Agriculture Land Pervious (AgPERV)-Hydrologic Soil Group B	Pervious	0.33	
***Agriculture Land Pervious (AgPERV)- Hydrologic Soil Group C	Pervious	0.67	
***Agriculture Land Pervious (AgPERV)-Hydrologic Soil Group C/D	Pervious	0.85	
***Agriculture Land Pervious (AgPERV)- Hydrologic Soil Group D	Pervious	1.02	

Table 7: Distinct average annual phosphorus load export rates (PLERs) used to calculate composite PLERs for calculating baseline phosphorus loads for CRW -Draft MA MS4 Permit

Pervious Area (PA) PLER Category	Applicable Land Use Groups	Representative Annual Mean TP Concentration	Comments on Methodology
Developed Land	Commercial, Industrial, All Residential, Open Land & Highway	0.3 mg/L for runoff	Runoff yields derived from SWMM and P8 - Curve Number continuous simulation HRU modeling with assumed TP concentration of 0.3 mg/L for pervious runoff from developed lands. TP of 0.3 mg/L is based on TB-9 (CSN, 2011), and other PLER literature and assumes 50% of pervious developed lands receive phosphorus fertilization
Forest	Forest	0.1 mg/L for runoff 0.015 mg/L for baseflow	Runoff yields derived from P8 - Curve Number continuous simulation HRU modeling with assumed TP concentration of 0.1 mg/L for pervious runoff from forested lands. Baseflow volume determined from USGS study of Lower Charles River (Breault, et al, 2002). Baseflow annual mean concentration of 0.015 mg/L is representative of uncontaminated groundwater inflow.
Agriculture	Agriculture	0.5 mg/L for runoff	Runoff yields derived from SWMM and P8 - Curve Number continuous simulation HRU modeling with assumed TP concentration of 0.5 mg/L for pervious runoff from developed lands. TP of 0.5 mg/L is based on PLER literature.

Table 8: Representative Annual Mean Phosphorus Concentrations used to Calculate Distinct Pervious Area phosphorus load Export Rates

Community	Calculated Composite Phosphorus Load Export Rates (CPLER) based on TIA and HSG distribution, kg/ha/yr								
	Commercial	Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Highway	open land	Agriculture	Forest (runoff & watershed baseflow)
Arlington	1.36		1.22			0.68	0.57	0.33	0.18
Ashland	1.02	0.52	1.01	0.55	0.56		0.47	0.66	0.21
Bellingham	1.36	1.42	0.96	0.49	0.40	0.82	0.29	0.51	0.19
Belmont	1.06	0.72	1.21	0.77	0.69	1.00	0.61	0.53	0.21
Boston	1.51	1.68	1.57	0.72	0.63	1.31	0.49	0.58	0.23
Brookline	1.46	1.37	1.52	0.80	0.61	1.23	0.52	0.61	0.22
Cambridge	1.66	1.89	1.83	0.91	0.58	1.25	0.43		0.57
Dedham	1.38	1.73	1.10	0.67	0.40	0.97	0.52	0.35	0.22
Dover	0.99			0.39	0.39	0.31	0.29	0.47	0.20
Foxborough					0.61				0.20
Franklin	1.36	1.40	1.09	0.55	0.37	0.93	0.39	0.45	0.19
Holliston	1.11	1.18	0.83	0.46	0.40	0.91	0.35	0.55	0.20
Hopedale	1.06	1.59	0.20	0.47	0.42	0.73	0.31	0.75	0.18
Hopkinton	1.30	1.44	0.93	0.58	0.49		0.77	0.74	0.21
Lexington	1.21	1.29	1.06	0.65	0.58	0.80	0.40	0.70	0.22
Lincoln	1.06	1.28	0.84	0.37	0.40	1.04	0.31	0.42	0.20
Medfield	1.28	1.04	1.08	0.53	0.42	0.67	0.28	0.40	0.20
Medway	1.32	1.20	0.91	0.52	0.41		0.31	0.42	0.20
Mendon	1.46	1.33	1.20	0.20	0.36		0.22	0.52	0.17
Milford	1.52	1.50	1.16	0.65	0.44	0.67	0.42	0.71	0.19
Millis	1.37	1.55	0.94	0.39	0.35	0.78	0.27	0.41	0.20
Natick	1.32	1.42	1.14	0.71	0.50	0.86	0.42	0.57	0.21
Needham	1.41	1.69	1.04	0.67	0.45	0.90	0.36	0.28	0.20
Newton	1.42	1.60	1.26	0.76	0.51	1.00	0.43	0.42	0.21
Norfolk	1.04	1.19	1.08	0.38	0.32	0.36	0.29	0.44	0.18
Somerville	1.74	1.92	1.97			1.40	0.77		0.24
Sherborn	0.96	1.20	0.90	0.20	0.39	0.87	0.31	0.50	0.20
Walpole	1.12		1.87	0.38	0.45	1.06	0.36	0.39	0.20
Waltham	1.37	1.58	1.32	0.69	0.52	1.01	0.56	0.41	0.20
Watertown	1.58	1.73	1.38			0.89	0.38	0.50	0.19
Wayland	1.20	0.20	1.17	0.72	0.42	0.35	0.26	1.05	0.18
Wellesley	1.08	1.71	1.20	0.69	0.46	0.87	0.36	0.25	0.19
Weston	1.15	0.84	0.95	0.54	0.42	0.95	0.44	0.40	0.19
Westwood	1.12	1.49	1.24	0.69	0.51	0.75	0.51	0.46	0.21
Wrentham	1.18	1.69	0.77	0.35	0.30	0.74	0.31	0.32	0.17
Totals	1.38	1.49	1.36	0.63	0.42	0.98	0.41	0.46	0.20

Table 9: Calculated land use based composite PLERs for community area within the CRW by municipality less MassDOT and MassDCR land area

MassDOT CRW	Composite Phosphorus Load Export Rates (CPLER) based on TIA and HSG distribution, kg/ha/yr								
Community	Commercial	Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Highway	open land	Agriculture	Forest (runoff & baseflow)
Arlington	0.81		0.82			1.12			0.23
Ashland							1.60		1.18
Bellingham	1.28	1.74	1.70	1.50	1.09	0.73	0.61	1.67	0.20
Belmont	2.17		1.82		1.64	1.29			2.26
Boston	1.97					1.50	1.31		0.36
Brookline	1.80	2.00	2.49	1.93	1.46	1.46	1.58		0.72
Cambridge	1.90	1.95	2.60			1.50	1.66		
Dedham	1.70	1.96	2.23	1.82	1.22	0.97	1.44		0.25
Dover					1.13	1.07		0.99	
Foxborough					1.38				0.68
Franklin	1.79	1.81	2.61	1.42	1.25	0.85	1.10	1.11	0.21
Holliston	1.68	1.72	2.11	1.80	1.23		1.52	1.53	1.00
Hopedale	1.77	1.87	2.12	1.48	1.46	1.33			1.00
Hopkinton		0.23				0.57			0.21
Lexington	1.25	0.75	1.88	0.70	0.99	0.97	0.50	0.68	0.23
Lincoln					0.40	1.46			0.36
Medfield	1.49				1.39	0.96	1.68		0.29
Medway		0.20				0.49	0.20		0.16
Mendon	1.88	1.94	2.50		1.65			1.71	1.55
Milford	1.71	1.72	1.93	1.61	1.33	0.55	0.40		0.18
Millis				2.44		1.34		0.98	0.80
Natick	1.92	0.51	2.51	1.69	1.39	1.05			0.35
Needham	1.52	1.05	1.20	0.94	1.31	0.96	1.60	1.61	0.22
Newton	1.71	1.69	2.06	1.68	1.00	1.28	0.52	0.92	0.41
Norfolk	2.01	2.00			1.71	1.51	1.69		1.65
Somerville	1.97	1.72	2.58			1.50			
Sherborn					4.63			1.05	1.30
Walpole	2.01		2.59	1.78	1.23	1.48			1.34
Waltham	1.27	1.04	2.09	1.68	0.51	1.06	1.07		0.23
Watertown	1.91	1.54	2.39			1.35	1.55		1.17
Wayland				1.16		1.02			0.23
Wellesley	1.72		2.19	1.97	1.41	1.25			0.89
Weston	1.30	1.68	1.03	1.39	1.17	1.09	0.72	1.18	0.24
Westwood	1.08	1.19		2.00	0.96	0.95	0.89	0.94	0.23
Wrentham	1.69	1.36		1.53	1.25	0.71	1.03	1.26	0.23
Totals	1.63	1.59	2.06	1.59	1.23	0.94	0.79	1.01	0.23

Table 10: Calculated composite PLERs for MassDOT area within the CRW by municipality

DCR CRW	Composite Phosphorus Load Export Rates (CPLER) based on TIA and HSG distribution, kg/ha/yr								
Community	Commercial	Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Highway	open land	Agriculture	Forest (runoff & baseflow)
Arlington	1.60		1.86			1.28	1.45		2.01
Ashland									
Bellingham									

Belmont	1.20	0.05	1.17		0.26	1.47	0.65		0.20
Boston	0.51		0.20				1.07		0.27
Brookline	1.53	1.44	1.72	1.30			0.67	1.22	0.25
Cambridge	0.47	0.43	0.51	0.51	0.51	0.44	0.26		0.16
Dedham	1.14	1.92	0.11	0.98	0.40	0.90	0.32		0.23
Dover	0.65				0.38		0.13	0.52	0.17
Foxborough									
Franklin	1.05	1.62	0.56	0.58	0.19		0.25	0.81	0.19
Holliston									
Hopedale									
Hopkinton									
Lexington	1.10	0.92	0.20		0.48		0.32		0.21
Lincoln									
Medfield	0.45	0.21			0.26	0.34	0.19	0.20	0.20
Medway									
Mendon									
Milford			0.67				0.79		0.21
Millis									
Natick			0.52						0.15
Needham	0.86	0.60	0.20	0.46	0.17	0.54	0.31	1.05	0.21
Newton	1.10	0.64	1.00	1.34	0.05	0.56	0.71	0.33	0.22
Norfolk					0.31			0.29	0.23
Somerville							0.51		
Sherborn									0.25
Walpole									
Waltham	0.71	1.49	1.23		0.19	1.25	0.28	0.86	0.19
Watertown	0.82	1.17	1.26				0.23		0.21
Wayland						0.61			0.26
Wellesley	0.48	0.98	1.09	0.52	0.31	0.51	0.07	0.17	0.17
Weston	0.47			0.05	0.44	0.52	0.20	0.32	0.19
Westwood						1.14			0.16
Wrentham				0.15	0.52		0.47		0.22
Totals	1.00	1.38	1.35	0.89	0.33	0.96	0.39	0.33	0.20

Table 11: Calculated land use based composite PLERs for DCR area within the CRW

Charles	Composite Phosphorus Load Export Rates (CPLER) based on TIA and HSG distribution, kg/ha/yr								
Community	Commercial	Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Highway	Open Land	Agriculture	Forest (runoff & baseflow)
Arlington	1.32		1.23			1.26	0.61	0.33	0.18
Ashland	1.02	0.52	1.01	0.55	0.56		0.52	0.66	0.21
Bellingham	1.35	1.42	0.96	0.50	0.40	0.76	0.29	0.51	0.19
Belmont	1.06	0.72	1.21	0.77	0.65	1.29	0.61	0.53	0.21
Boston	1.51	1.68	1.57	0.72	0.63	1.31	0.49	0.58	0.23
Brookline	1.47	1.38	1.53	0.82	0.61	1.25	0.53	0.61	0.23

Cambridge	1.47	1.79	1.81	0.90	0.57	1.34	0.40		0.18
Dedham	1.40	1.78	1.11	0.68	0.40	0.94	0.53	0.35	0.22
DoverU	0.92			0.39	0.39	0.31	0.26	0.47	0.19
Foxborough					0.70				0.21
Franklin	1.37	1.40	1.09	0.55	0.37	0.88	0.40	0.45	0.19
Holliston	1.12	1.18	0.84	0.46	0.41	0.91	0.35	0.55	0.20
Hopedale	1.08	1.60	2.01	0.53	0.42	0.76	0.31	0.75	0.19
Hopkinton	1.30	1.43	0.93	0.58	0.49	0.57	0.77	0.74	0.21
Lexington	1.21	1.26	1.07	0.65	0.59	0.97	0.40	0.70	0.22
Lincoln	1.06	1.28	0.84	0.37	0.40	1.05	0.31	0.42	0.20
Medfield	1.28	1.04	1.08	0.53	0.42	0.66	0.28	0.37	0.20
Medway	1.32	1.20	0.91	0.52	0.41	0.49	0.31	0.42	0.20
Mendon	1.51	1.35	1.27	0.20	0.44		0.22	0.52	0.18
Milford	1.52	1.50	1.16	0.65	0.45	0.56	0.42	0.71	0.19
Millis	1.37	1.55	0.94	0.39	0.35	0.78	0.27	0.41	0.20
Natick	1.35	1.42	1.14	0.71	0.50	0.98	0.42	0.57	0.21
Needham	1.40	1.66	1.04	0.67	0.45	0.95	0.36	0.28	0.20
Newton	1.43	1.60	1.26	0.76	0.51	1.15	0.43	0.42	0.21
Norfolk	1.05	1.20	1.08	0.38	0.32	0.37	0.29	0.44	0.18
Somerville	1.74	1.92	1.97			1.43	0.76		0.24
Sherborn	0.96	1.20	0.90	0.20	0.39	0.87	0.31	0.50	0.20
Walpole	1.13		2.15	0.54	0.45	1.06	0.36	0.39	0.20
Waltham	1.36	1.57	1.32	0.70	0.52	1.06	0.55	0.42	0.20
Watertown	1.55	1.70	1.38			0.89	0.37	0.50	0.21
Wayland	1.20	0.20	1.17	0.72	0.42	1.01	0.26	1.05	0.18
Wellesley	1.09	1.71	1.22	0.70	0.47	1.04	0.36	0.25	0.20
Weston	1.15	1.01	0.95	0.55	0.42	1.07	0.44	0.39	0.19
Westwood	1.12	1.46	1.24	0.69	0.51	0.95	0.51	0.47	0.21
Wrentham	1.19	1.69	0.77	0.37	0.32	0.71	0.31	0.33	0.17
Totals	1.38	1.50	1.36	0.63	0.42	0.96	0.41	0.46	0.20

Table 12: Calculated land use based composite PLERs for CRW area by municipality

5. EPA calculated average annual baseline watershed phosphorus loads (i.e., excluding WWTFs and CSOs) for Community only, MassDOT and DCR properties for each municipality within the CRW. Phosphorus loads were calculated by multiplying the areas of land use groups by the corresponding land use based composite PLERs calculated for each entity in each municipality as shown above. The phosphorus loads were summed and then compared to the reported watershed phosphorus load, taken from the two TMDL reports, to evaluate the adequacy of using the calculated composite PLERs (described above) for estimating baseline watershed phosphorus loads and associated reductions. A comparison of the results (see Table 13) shows that the estimated watershed phosphorus load derived by using the calculated composite PLERs agrees very well with the TMDL results (percent difference of only 2.3 %). Therefore, EPA has determined that use of the composite PLERs is appropriate for establishing baseline phosphorus loads and calculating phosphorus load reduction requirements for the draft MA MS 4 permit.

Watershed	Annual SW/watershed phosphorus load using calculated PLERs, kg/yr	Annual SW/watershed phosphorus load derived from TMDL Reports, kg/yr	Percent Difference
Entire Charles River Watershed	**41,555**	**40,611**	**2.3%**

Table 13: Comparison of stormwater phosphorus loads estimated using calculated composite PLERs with TMDL reported results

6. EPA calculated phosphorus load reduction requirements for community only, MassDOT, and DCR within each municipality for the CRW. Phosphorus load reductions were calculated by multiplying the land use based phosphorus loads calculated in step 5 by the appropriate reduction rates specified in the WLA portions of the TMDL Reports (see Table 14). As indicated, different reduction rates apply to the Upper CRW (above Watertown Dam) and Lower CRW (downstream of Watertown Dam) based on the two TMDL analyses.

   As indicated above in step number 4, the natural watershed dry weather baseflow phosphorus load was added to the forested land group phosphorus load so that the phosphorus load estimates and reductions for other land use groups would not include natural dry weather baseflow phosphorus load but only stormwater and illicit phosphorus loads. This was done because the reduction rates from the TMDL analyses are intended for the watershed phosphorus load excluding the natural baseflow load. For this analysis the natural baseflow phosphorus load is added to the forest load since no reductions are being called for from forested lands (i.e., 0% reduction of forest phosphorus load).

   For those communities that have land area in both the Upper CRW and Lower CRW, their phosphorus load reductions are equal to the sum of the phosphorus load reductions calculated for the municipality's area in each the Upper and Lower CRW using the rates specified in Table 4or Table 5. Table 14 provides the baseline watershed phosphorus loads, the calculated phosphorus load reductions for municipal only, MassDOT and DCR for each community in the CRW.

Community Annual Phosphorus Load Reduction by Municipality, Charles River Watershed (excludes reductions to be achieved by DOT and DCR)				MassDOT Annual Stormwater Phosphorus Load Reduction by Municipality, Charles River Watershed				DCR Annual Stormwater Phosphorus Load Reduction by Municipality, Charles River Watershed			
Community	Baseline Watershed Phosphorus Load, kg/yr	Required Watershed P load reduction, kg/yr	Required Percent Reduction in Phosphorus Load (%)	Community	Baseline Stormwater Phosphorus Load, kg/yr	Required Stormwater P load reduction, kg/yr	Required Percent Reduction in Phosphorus Load (%)	Community	Baseline Stormwater Phosphorus Load, kg/yr	Required Stormwater P load reduction, kg/yr	Required Percent Reduction in Phosphorus Load (%)
Arlington	110.8	71.0	64.1%	Arlington	0.83	0.53	64.6%	Arlington	9.7	6.2	64.2%
Ashland	67.4	28.2	41.8%	Ashland	0.27	0.03	9.4%	Ashland	0.0	0.0	0.0%
Bellingham	957.9	404.5	42.2%	Bellingham	48.3	27.9	57.7%	Bellingham	0.0	0.0	0.0%
Belmont	208.1	109.2	52.5%	Belmont	3.2	2.1	64.9%	Belmont	5.5	1.5	27.7%
Boston	7053.2	4247.1	60.2%	Boston	0.67	0.40	60.2%	Boston	0.34	0.18	53.7%
Brookline	1695.0	1004.6	59.3%	Brookline	29.4	17.1	57.9%	Brookline	19.9	8.5	42.7%
Cambridge	522.9	324.2	62.0%	Cambridge	18.1	11.2	62.0%	Cambridge	15.5	9.2	59.2%
Dedham	835.6	422.4	50.5%	Dedham	67.2	37.0	55.1%	Dedham	73.3	15.0	20.4%

Dover	832.8	180.1	21.6%	Dover	0.07	0.04	52.8%	Dover	34.7	6.8	19.6%
Foxborough	1.58	0.37	23.2%	Foxborough	0.25	0.11	44.5%	Foxborough	0.0	0.0	0.0%
Franklin	2366.9	1024.3	43.3%	Franklin	89.1	51.1	57.3%	Franklin	57.8	1.2	2.1%
Holliston	1554.6	502.5	32.3%	Holliston	18.0	7.4	41.4%	Holliston	0.0	0.0	0.0%
Hopedale	107.4	46.9	43.6%	Hopedale	6.2	3.6	58.1%	Hopedale	0.0	0.0	0.0%
Hopkinton	292.7	89.4	30.6%	Hopkinton	8.7	4.7	53.8%	Hopkinton	0.0	0.0	0.0%
Lexington	549.7	253.4	46.1%	Lexington	106.4	62.8	59.0%	Lexington	5.5	1.4	24.9%
Lincoln	594.7	127.9	21.5%	Lincoln	0.21	0.07	33.7%	Lincoln	0.0	0.0	0.0%
Medfield	966.5	351.4	36.4%	Medfield	0.35	0.13	37.8%	Medfield	19.4	1.3	6.5%
Medway	1065.9	402.2	37.7%	Medway	1.8	1.0	55.7%	Medway	0.0	0.0	0.0%
Mendon	28.8	11.5	39.9%	Mendon	3.5	1.6	47.0%	Mendon	0.0	0.0	0.0%
Milford	1653.9	836.3	50.6%	Milford	75.6	43.2	57.1%	Milford	0.59	0.19	32.9%
Millis	972.5	302.9	31.2%	Millis	0.17	0.02	12.6%	Millis	0.0	0.0	0.0%
Natick	1147.8	508.6	44.3%	Natick	25.3	15.1	59.6%	Natick	0.22	0.11	51.1%
Needham	1828.9	1009.5	55.2%	Needham	70.9	41.9	59.1%	Needham	41.9	1.6	3.9%
Newton	4067.1	2478.2	60.9%	Newton	130.0	81.4	62.6%	Newton	37.2	9.4	25.4%
Norfolk	1005.7	286.6	28.5%	Norfolk	3.8	0.9	23.7%	Norfolk	10.9	0.3	2.6%
Somerville	652.9	404.8	62.0%	Somerville	17.7	11.0	62.0%	Somerville	0.35	0.22	62.0%
Sherborn	847.7	156.6	18.5%	Sherborn	0.03	0.004	13.5%	Sherborn	0.0	0.0	0.0%
Walpole	159.0	37.5	23.6%	Walpole	2.9	0.9	31.9%	Walpole	0.0	0.0	0.0%
Waltham	2985.0	1806.5	60.5%	Waltham	74.5	45.4	60.9%	Waltham	43.3	16.2	37.4%
Watertown	1163.9	725.8	62.4%	Watertown	7.3	4.5	61.2%	Watertown	21.5	11.6	53.8%
Wayland	47.7	20.2	42.4%	Wayland	10.1	6.1	60.8%	Wayland	0.00	0.00	0.0%
Wellesley	1506.5	868.5	57.6%	Wellesley	64.7	36.8	56.9%	Wellesley	8.7	1.9	22.3%
Weston	1192.6	383.4	32.1%	Weston	114.2	65.7	57.6%	Weston	14.0	3.5	24.8%
Westwood	394.6	160.4	40.7%	Westwood	18.9	10.7	56.6%	Westwood	0.28	0.16	59.2%
Wrentham	619.7	211.1	34.1%	Wrentham	46.0	23.2	50.4%	Wrentham	12.0	0.19	1.6%
Totals	40058.1	19798.1	49.4%	Totals	1064.8	615.6	57.8%	Totals	432.5	96.6	22.3%

Table 14: Watershed phosphorus load reductions for community, MassDOT and DCR for each municipality in the CRW

7. The WLA percent reduction rates taken from the TMDL reports are intended to apply to the total land based watershed phosphorus load, which includes the presence of illicit discharges (but excludes WWTFs and CSOs). Therefore, EPA took an additional step to estimate the portion of the phosphorus load reduction that would be achieved through elimination of illicit discharges (required under the permit). Subtraction of the illicit phosphorus load from the total watershed phosphorus load reduction is needed to determine the stormwater only phosphorus load reduction requirement for the CRW.

   The portion of the land based watershed phosphorus load due to the presence of illicit sanitary discharges discharging to the Charles River is estimated to be 10% of the calculated phosphorus load from the commercial, industrial, and all residential land use groups. The resulting estimated illicit phosphorus load is 3,009 kg/yr, or approximately 7% of the total estimated land based watershed phosphorus load to the Charles River (41,555 kg/yr). For additional perspective, the illicit phosphorus load estimate is 0.7% of the estimated total sanitary sewage phosphorus load (434,000 kg/yr) generated by the resident population (801,301) in the CRW. The illicit phosphorus load estimate is based on considering the magnitude of illicit loads that have been already identified and eliminated from communities within the CRW. For this permit and for the associated stormwater phosphorus load reduction calculations, the illicit phosphorus load value should be considered a default value that will be re-evaluated and refined, if needed, in future permit re-issuances.

Communities will be required to track and report illicit phosphorus load reductions over the course of each permit term so that EPA can make needed adjustments to the baseline phosphorus loads subject to reduction requirements in future permit issuances.

8. EPA calculated stormwater phosphorus load reduction requirements for community, MassDOT and DCR for each municipality by taking into account the expected reductions from illicit discharge elimination work. First, the total stormwater phosphorus load reduction for the CRW is determined by subtracting the illicit phosphorus load from the total watershed phosphorus load reduction determined in step 6 (see Table 15):

    20,510 kg/yr – 3,009 kg/yr = 17,501 kg/yr

    (Total watershed phosphorus load reduction - Illicit phosphorus load = Stormwater phosphorus load reduction)

    Next, watershed load reductions calculated in step 6 for community only in each municipality were reduced by the illicit load calculated for that community. The illicit load calculated for each community equals 10% of the phosphorus load generated by commercial, industrial and residential land area within the CRW portion of the community. No adjustments were made to the phosphorus load reduction requirements for MassDOT and DCR (step 6) because it is assumed that the municipality's IDDE program will be the means for achieving the illicit load reductions.

    While community specific illicit phosphorus loads were calculated to determine initial permit stormwater phosphorus load reduction requirements for each community, the communities should not view the calculated illicit load reductions as their own credits but as watershed-wide credits. If implementation of IDDE programs should result in illicit phosphorus load reduction greater than 3,009 kg/yr in the future, then the resulting reduced stormwater phosphorus load reduction requirement (to be calculated by EPA in future permits) would be shared by all communities. Similarly, if the IDDE programs ultimately achieve less than the 3,009 kg/yr illicit load reduction, then the resulting increased stormwater phosphorus load reduction that would be needed would also be shared by all communities. This approach prevents any community that may have a disproportionally large amount of illicit load from not doing its fair share of stormwater phosphorus load reduction work.

    Table 15 provides the proposed stormwater phosphorus load reduction requirements for the community, MassDOT and DCR for each municipality assuming that all CRW area is managed.

Community Annual Stormwater Phosphorus Load Reduction by Municipality, Charles River Watershed (excludes illicits and reductions to be achieved by DOT and DCR)				MassDOT Annual Stormwater Phosphorus Load Reduction by Municipality, Charles River Watershed				DCR Annual Stormwater Phosphorus Load Reduction by Municipality, Charles River Watershed			
Community	Baseline Phosphorus Load, kg/yr	Required Stormwater P load reduction, kg/yr	Required Percent Reduction in Stormwater only Phosphorus Load	Community	Baseline Stormwater Phosphorus Load, kg/yr	Required Stormwater P load reduction, kg/yr	Required Percent Reduction in Phosphorus Load (%)	Community	Baseline Stormwater Phosphorus Load, kg/yr	Required Stormwater P load reduction, kg/yr	Required Percent Reduction in Phosphorus Load (%)

			(%)								
Arlington	110.8	59.9	54.0%	Arlington	0.83	0.53	64.6%	Arlington	9.7	6.2	64.2%
Ashland	67.4	23.9	35.5%	Ashland	0.27	0.03	9.4%	Ashland	0.0	0.0	0.0%
Bellingham	957.9	344.3	35.9%	Bellingham	48.3	27.9	57.7%	Bellingham	0.0	0.0	0.0%
Belmont	208.1	93.9	45.1%	Belmont	3.2	2.1	64.9%	Belmont	5.5	1.5	27.7%
Boston	7053.2	3632.8	51.5%	Boston	0.67	0.40	60.2%	Boston	0.34	0.18	53.7%
Brookline	1695.0	853.0	50.3%	Brookline	29.4	17.1	57.9%	Brookline	19.9	8.5	42.7%
Cambridge	522.9	273.5	52.3%	Cambridge	18.1	11.2	62.0%	Cambridge	15.5	9.2	59.2%
Dedham	835.6	354.9	42.5%	Dedham	67.2	37.0	55.1%	Dedham	73.3	15.0	20.4%
Dover	832.8	150.5	18.1%	Dover	0.07	0.04	52.8%	Dover	34.7	6.8	19.6%
Foxborough	1.6	0.26	16.5%	Foxborough	0.25	0.11	44.5%	Foxborough	0.0	0.0	0.0%
Franklin	2366.9	868.8	36.7%	Franklin	89.1	51.1	57.3%	Franklin	57.8	1.2	2.1%
Holliston	1554.6	423.7	27.3%	Holliston	18.0	7.4	41.4%	Holliston	0.0	0.0	0.0%
Hopedale	107.4	38.8	36.1%	Hopedale	6.2	3.6	58.1%	Hopedale	0.0	0.0	0.0%
Hopkinton	292.7	72.7	24.8%	Hopkinton	8.7	4.7	53.8%	Hopkinton	0.0	0.0	0.0%
Lexington	549.7	213.6	38.9%	Lexington	106.4	62.8	59.0%	Lexington	5.5	1.4	24.9%
Lincoln	594.7	109.2	18.4%	Lincoln	0.21	0.07	33.7%	Lincoln	0.0	0.0	0.0%
Medfield	966.5	297.0	30.7%	Medfield	0.35	0.13	37.8%	Medfield	19.4	1.3	6.5%
Medway	1065.9	337.3	31.6%	Medway	1.8	1.0	55.7%	Medway	0.0	0.0	0.0%
Mendon	28.8	9.5	32.9%	Mendon	3.5	1.6	47.0%	Mendon	0.0	0.0	0.0%
Milford	1653.9	708.3	42.8%	Milford	75.6	43.2	57.1%	Milford	0.59	0.19	32.9%
Millis	972.5	261.2	26.9%	Millis	0.17	0.02	12.6%	Millis	0.0	0.0	0.0%
Natick	1147.8	428.8	37.4%	Natick	25.3	15.1	59.6%	Natick	0.22	0.11	51.1%
Needham	1828.9	852.3	46.6%	Needham	70.9	41.9	59.1%	Needham	41.9	1.6	3.9%
Newton	4067.1	2100.3	51.6%	Newton	130.0	81.4	62.6%	Newton	37.2	9.4	25.4%
Norfolk	1005.7	244.4	24.3%	Norfolk	3.8	0.9	23.7%	Norfolk	10.9	0.3	2.6%
Somerville	652.9	344.9	52.8%	Somerville	17.7	11.0	62.0%	Somerville	0.35	0.22	62.0%
Sherborn	847.7	136.0	16.0%	Sherborn	0.032	0.004	13.5%	Sherborn	0.0	0.0	0.0%
Walpole	159.0	31.0	19.5%	Walpole	2.9	0.9	31.9%	Walpole	0.0	0.0	0.0%
Waltham	2985.0	1531.2	51.3%	Waltham	74.5	45.4	60.9%	Waltham	43.3	16.2	37.4%
Watertown	1163.9	613.3	52.7%	Watertown	7.3	4.5	61.2%	Watertown	21.5	11.6	53.8%
Wayland	47.7	17.0	35.7%	Wayland	10.1	6.1	60.8%	Wayland	0.0	0.0	0.0%
Wellesley	1506.5	734.1	48.7%	Wellesley	64.7	36.8	56.9%	Wellesley	8.7	1.9	22.3%
Weston	1192.6	318.3	26.7%	Weston	114.2	65.7	57.6%	Weston	14.0	3.5	24.8%
Westwood	394.6	134.3	34.0%	Westwood	18.9	10.7	56.6%	Westwood	0.28	0.16	59.2%
Wrentham	619.7	176.7	28.5%	Wrentham	46.0	23.2	50.4%	Wrentham	12.0	0.19	1.6%
Totals	40058.1	16789.4	41.9%	Totals	1064.8	615.6	57.8%	Totals	432.5	96.6	22.3%

Table 15: Stormwater only phosphorus load reduction requirements for community only, MassDOT and DCR for each municipality in the CRW

9. EPA calculated stormwater phosphorus load reduction requirements for designated Urban Area (UA) within each CRW municipality. UA is defined by the 2010 census and is used to define the minimum required jurisdictional area for MS4 permittees. UA was determined through a GIS analyses and represents a subset of areas used in the above discussed analysis. The same approach as described above in step numbers 6,7 and 8 was used to calculate the stormwater phosphorus load reduction requirements for UA community only, MassDOT and DCR in each municipality. Table 16 presents the UA stormwater only phosphorus load reduction requirements for community only, MassDOT and DCR with each municipality.

Community Annual Phosphorus Load Reduction by Municipality, Urban Area Charles River Watershed (excludes illicits and reductions to be achieved by MassDOT and DCR)				MADOT Annual Stormwater Phosphorus Load Reduction by Municipality, Urban Area Charles River Watershed				DCR Annual Stormwater Phosphorus Load Reduction by Municipality, Urban Area Charles River Watershed			
Community	Baseline Watershed	Required Stormwater P load	Required Percent Reductio	Community	Baseline Stormwater	Required Stormwater P load	Required Percent Reductio	Community	Baseline Stormwater	Required Stormwater P load	Required Percent Reductio

	Phosphorus Load, kg/yr	reduction, kg/yr	n in Stormwater only Phosphorus Load (%)		Phosphorus Load, kg/yr	reduction, kg/yr	n in Phosphorus Load (%)		Phosphorus Load, kg/yr	reduction, kg/yr	n in Phosphorus Load (%)
Arlington	110.8	59.9	54.0%	Arlington	0.8	0.5	64.6%	Arlington	9.7	6.2	64.2%
Ashland	67.4	23.9	35.5%	Ashland	0.27	0.03	9.4%	Ashland	0.0	0.0	0.0%
Bellingham	812.0	303.8	37.4%	Bellingham	48.3	27.9	57.7%	Bellingham	0.0	0.0	0.0%
Belmont	208.1	93.9	45.1%	Belmont	3.2	2.1	64.9%	Belmont	5.5	1.5	27.7%
Boston	7053.2	3632.8	51.5%	Boston	0.67	0.40	60.2%	Boston	0.34	0.18	53.7%
Brookline	1695.0	853.0	50.3%	Brookline	29.4	17.1	57.9%	Brookline	19.9	8.5	42.7%
Cambridge	522.9	273.5	52.3%	Cambridge	18.1	11.2	62.0%	Cambridge	15.5	9.2	59.2%
Dedham	835.6	354.9	42.5%	Dedham	67.2	37.0	55.1%	Dedham	73.3	15.0	20.4%
Dover	282.2	66.5	23.6%	Dover	0.07	0.04	52.8%	Dover	15.5	4.5	28.9%
Foxborough	1.6	0.26	16.5%	Foxborough	0.25	0.11	44.5%	Foxborough	0.0	0.0	0.0%
Franklin	2334.4	864.4	37.0%	Franklin	89.1	51.1	57.3%	Franklin	52.2	1.2	2.3%
Holliston	1369.5	397.6	29.0%	Holliston	18.0	7.4	41.4%	Holliston	0.0	0.0	0.0%
Hopedale	107.3	38.7	36.1%	Hopedale	6.2	3.6	58.1%	Hopedale	0.0	0.0	0.0%
Hopkinton	279.9	71.9	25.7%	Hopkinton	8.7	4.7	53.9%	Hopkinton	0.0	0.0	0.0%
Lexington	544.4	212.3	39.0%	Lexington	106.4	62.8	59.0%	Lexington	5.5	1.4	24.9%
Lincoln	366.9	70.6	19.2%	Lincoln	0.21	0.07	33.7%	Lincoln	0.0	0.0	0.0%
Medfield	838.0	288.8	34.5%	Medfield	0.34	0.13	39.1%	Medfield	19.3	1.3	6.6%
Medway	1040.1	328.2	31.6%	Medway	1.8	1.0	55.7%	Medway	0.0	0.0	0.0%
Mendon	10.4	4.7	44.9%	Mendon	3.1	1.4	45.2%	Mendon	0.0	0.0	0.0%
Milford	1528.4	698.4	45.7%	Milford	68.0	39.9	58.7%	Milford	0.59	0.19	32.9%
Millis	502.9	171.4	34.1%	Millis	0.12	0.02	15.6%	Millis	0.0	0.0	0.0%
Natick	1032.4	401.6	38.9%	Natick	25.3	15.1	59.6%	Natick	0.22	0.11	51.1%
Needham	1828.1	852.2	46.6%	Needham	70.8	41.9	59.1%	Needham	41.9	1.6	3.9%
Newton	4067.1	2100.3	51.6%	Newton	130.0	81.4	62.6%	Newton	37.2	9.4	25.4%
Norfolk	1002.7	243.8	24.3%	Norfolk	3.8	0.90	23.7%	Norfolk	10.9	0.28	2.6%
Somerville	652.9	344.9	52.8%	Somerville	17.7	11.0	62.0%	Somerville	0.35	0.22	62.0%
Sherborn	203.3	43.0	21.1%	Sherborn	0.0	0.0	0.0	Sherborn	0.0	0.0	0.0%
Walpole	159.0	31.0	19.5%	Walpole	2.9	0.9	31.9%	Walpole	0.0	0.0	0.0%
Waltham	2985.0	1531.2	51.3%	Waltham	74.5	45.4	60.9%	Waltham	43.3	16.2	37.4%
Watertown	1163.9	613.3	52.7%	Watertown	7.3	4.5	61.2%	Watertown	21.5	11.6	53.8%
Wayland	47.7	17.0	35.7%	Wayland	10.1	6.1	60.8%	Wayland	0.0	0.0	0.0%
Wellesley	1506.5	734.1	48.7%	Wellesley	64.7	36.8	56.9%	Wellesley	8.7	1.9	22.3%
Weston	1192.6	318.3	26.7%	Weston	114.2	65.7	57.6%	Weston	14.0	3.5	24.8%
Westwood	364.1	128.0	35.2%	Westwood	18.9	10.7	56.6%	Westwood	0.28	0.16	59.2%
Wrentham	558.3	164.2	29.4%	Wrentham	44.0	22.4	51.0%	Wrentham	8.2	0.19	2.3%
Totals	37274.8	16332.3	43.8%	Totals	1054.5	611.1	58.0%	Totals	403.9	94.3	23.3%

Table 16: phosphorus load reduction requirements for community only, MassDOT and DCR for each municipality within designated urban area of the CRW

<u>(H) Phosphorus Control Plan Requirements and Cost</u>

General Information: Appendix F A.I to the Draft Permit requires permittees to develop and implement Phosphorus Control Plans (PCPs) to reduce their discharges of excessive phosphorus load to the Charles River and its tributaries. The PCP is a multi-step process that shall include the implementation of non-structural and structural stormwater best management practices (BMPs) to achieve the stormwater phosphorus load reductions specified in tables F-1 or F-2 of Appendix F to the Draft Permit (which are rounded values of the values displayed in Tables 16 or 17 in section G above).

A major component of developing the PCP will be identifying the non-structural and structural BMPs that the permittee plans to implement to achieve stormwater phosphorus load reduction requirements. To this end, EPA has developed an accounting system for quantifying stormwater phosphorus load reduction credits for several non-structural and structural BMPs that are provided in Attachments 2 and 3 to Appendix F to the Draft Permit, respectively. The approach used to determine stormwater phosphorus load reduction requirements (described above in Section G of this Part) and quantify source area stormwater phosphorus loads for calculating reduction credits for non-structural and structural BMPs (described below in Sections I and J, respectively of this Part) are consistent so that valid reduction credits can be subtracted directly from the permittee's outstanding stormwater phosphorus load reduction amount. This approach serves the following purposes:

- stormwater phosphorus load reduction amounts will be quantified by all permittees using a consistent approach and with credible BMP performance information that EPA has determined to be representative of long-term cumulative reduction rates;
- stormwater phosphorus load reductions can be calculated for the entire watershed by summing the individual stormwater phosphorus load reductions from all individual CRW permittees. This will assist EPA and MassDEP in tracking phosphorus load reduction progress for the watershed and relating reduction estimates to future ambient water quality monitoring data; and
- Eliminates the need for permittees to develop their own models and estimates using potentially disparate sources of information and assumptions and thus, allows permittees to move forward in the relatively near future with the needed information to develop the PCP.

Costs for Structural stormwater Controls: The costs for developing and implementing stormwater management retrofit plans that involve installation of structural stormwater controls in urban areas are significant. The above mentioned costs are estimated capital costs and do not reflect the "real time" cost of implementing programs to carry out PCPs over an extended schedule such as the proposed schedule of 20 years. Sustainable funding programs are designed to collect fees from property owners based on the amounts of impervious area or other metrics related to stormwater runoff volumes generated by properties within the watershed. In the 2011 study, *Sustainable stormwater Funding Evaluation for the Upper Charles River Communities of Bellingham, Franklin, and Milford, MA,* (Upper Charles Funding study) the Horsley Witten Group (HWG) evaluated potential program options designed to raise adequate funds through setting fees (http://www.epa.gov/region1/npdes/charlesriver/pdfs/20110930-SWUtilityReport.pdf). To ascertain the fees needed, the project estimated total costs (capital and operation and maintenance (O&M) costs) for using structural controls to achieve TMDL phosphorus load reductions. The study estimated the capitol cost to achieve the TMDL phosphorus load reduction for the three communities to be $181 million.

The study evaluated potential funding programs that could generate sustainable revenue streams based on applying fees for varying implementation schedules (10, 15, 20 and 25 years). Monthly fees for typical residential units (termed equivalent residential unit or ERU) that would be needed to adequately fund implementation of structural controls to achieve the stormwater TMDL phosphorus load reductions were estimated for varying schedules and different approaches. One approach used in the study, referred to as the Back-End loading option, best reflects the current phased PCP requirements in the Draft Permit, which allows permittees to ramp up the rate of stormwater phosphorus load reduction in each subsequent phase. Average monthly fees per ERU for the 20 year compliance schedule were estimated to be approximately $19, $13, and $20 (in 2011 dollars) for Milford, Bellingham, and Franklin, respectively. In other words, the average annual cost for a typical single family residence (SFR) in Milford, Bellingham and Franklin would be approximately $230, $140, and $260 per year, respectively. In this approach, non-single family residential properties' fees would be assessed based on the amount of its impervious area (IA) expressed in terms of ERUs. For example, in Franklin and ERU is 3,252 square feet of IA so that one acre of IA equals13.4 ERUs. Therefore, one acre of IA in Franklin would have a calculated fee of $124 per month or $1,490 per year.

The Upper Charles Funding study's estimate of $181 million for the three communities assumes all phosphorus load reduction will be accomplished in the future through stormwater management BMPs. In reality, a portion of the load reduction has been and will be achieved through illicit discharge detection and elimination (IDDE) programs required by the permit and through the implementation of stormwater controls already built. Additionally, as acknowledged in the Upper Charles Funding study, EPA has estimated that significant cost savings could be achieved through comprehensive stormwater management optimization analyses conducted during the planning stages for each phase of the PCP. As part of an **optimization** analysis, EPA estimated capital costs to achieve a 50% stormwater phosphorus load reduction at over 260 developed sites with widely varying site conditions in the three upper Charles River communities. The estimated unit costs including an additional 35% for engineering and contingencies range from $3,700 to $54,000 per pound of phosphorus removed ($/lb-phosphorus removed) with an overall average cost of $18,600/ lb-phosphorus removed ($41,000/kg-phosphorus removed).

According to Table 16 above, Milford, Bellingham and Franklin are required to achieve annual stormwater phosphorus load reductions of 752 kg, 372 kg, and 921 kg, respectively. Assuming the average cost of $41,000/ kg-phosphorus removed, this translates into optimized cost estimates of $31 million, $ 15 million and $ 38 million or a total of $84 million for the three towns. Using the 20 year schedule and the lower costs based on the optimization analysis, the monthly ERU costs to fund structural stormwater control implementation would be approximately half of the reported numbers at $ 9, $6 and $9 in Milford, Bellingham and Franklin, respectively.

It is difficult to predict the exact cost of future stormwater management activities due to the number of variables that will be encountered during implementation. The fact is costs could vary widely, easily by a factor of 5, depending on the planning approach taken and the ultimate choice of controls. Not all stormwater controls are equal in terms of stormwater phosphorus load reduction, and consequently, some are much more cost effective than others. Figure 4 illustrates the range in unit costs ($/lb-P removed) among several stormwater control technologies when designed to achieve a 50% phosphorus load reduction. Surface infiltration practices are far more cost effective than subsurface infiltration practices or highly engineered bio-retention and gravel wetland systems. Another important factor to be considered in planning is that the cost effectiveness of individual stormwater control technologies varies based on the design objectives. For example, Figure 5 shows the differences in estimated unit costs for design objectives of 50% and 65% phosphorus load reductions for several stormwater control technologies. In all cases, the unit costs for 65% phosphorus load reductions are notably higher than for the 50% reductions.

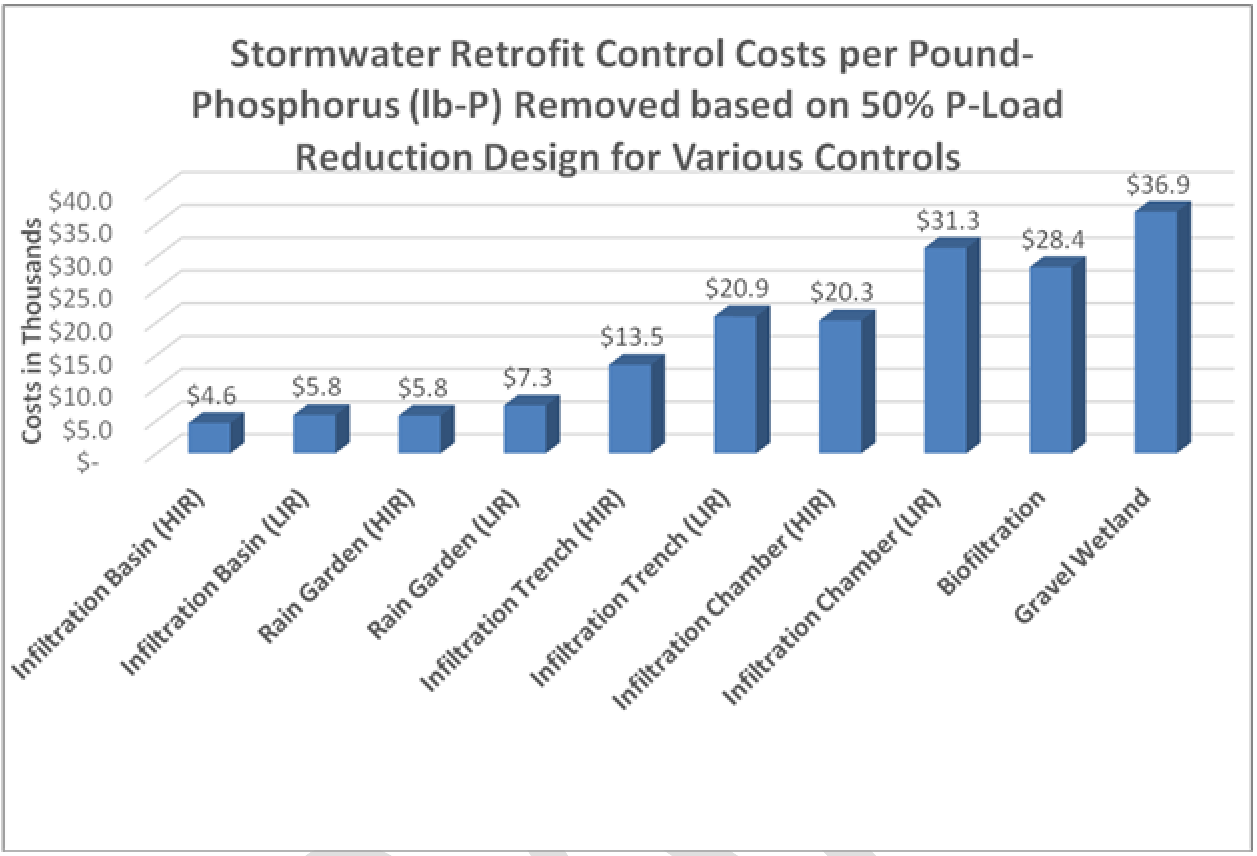

Figure 4: Estimated costs for various stormwater controls based 50% phosphorus load reduction design

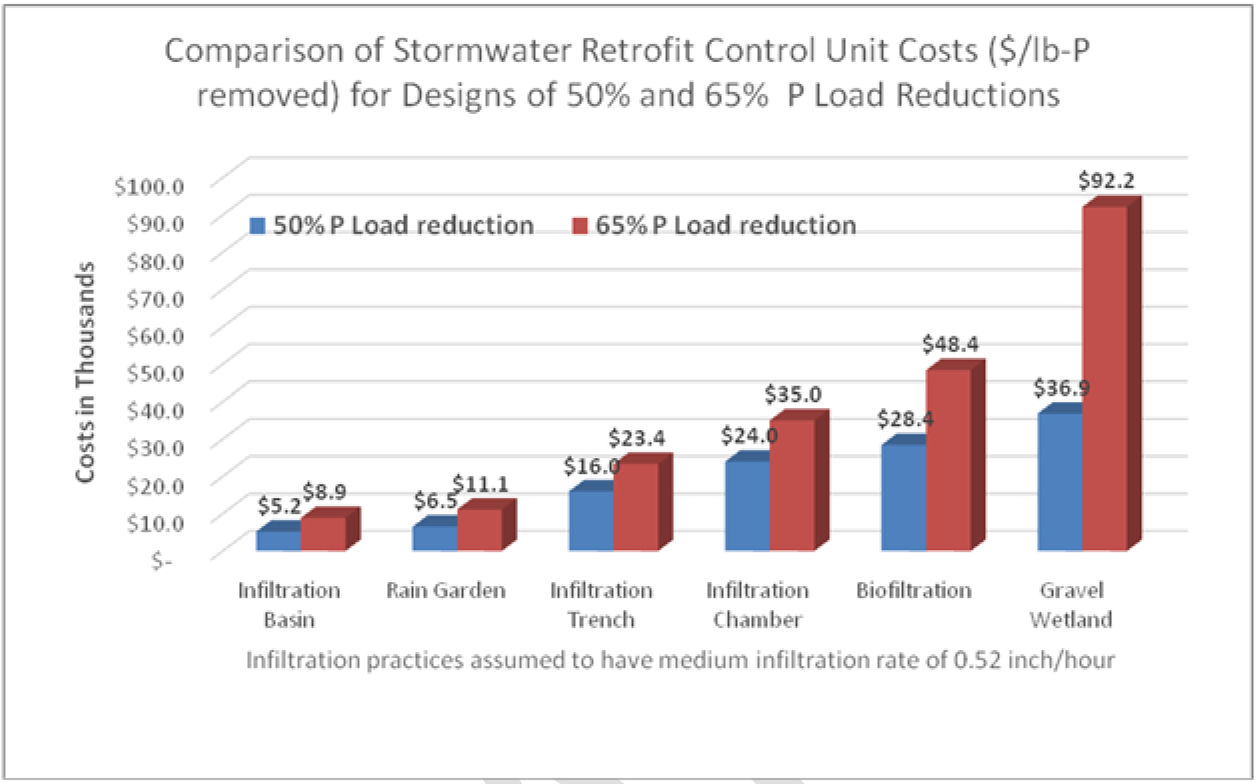

Figure 5: Unit cost comparison among various stormwater retrofit controls based on designs of 50% and 65% phosphorus load reductions

Again, all of the cost information discussed above assumes that controls are being built from scratch as stand alone projects. However, another significant opportunity to improve cost effectiveness of stormwater management programs is to incorporate stormwater retrofits into future re-development work. The City of Frankin, MA in the Upper Charles River watershed has done significant stormwater retrofit work as part of stand alone efforts and as part of other non-stormwater related redevelopment projects. In some cases, the city devoted labor and equipment to implement the projects, resulting in significantly reduced project costs. Another aspect of Franklin's work has been to eliminate unnecessary impervious surfaces, which reduces stormwater phosphorus loads and saves substantial money by reducing re-paving costs and annual snow plowing needs. In a recent analysis of green infrastructure benefits conducted by HWG for Franklin, unit costs were estimated for several projects with the following results: $ 1,650 to $ 4,900/lb-phosphorus removed for a surface infiltration systems; $10, 400 to$ 27,8000/lb-phosphorus removed for bio retention and infitration chamber systems; and an estimated **savings** of $34,600 for removing paved area. Overall, HWG estimated an average cost of $9,110/lb-phosphorus removed for the structural practices implemented by Franklin.

The purpose of providing the above cost information is to convey the following points:

- The capitol investment needed to comply with the PCP requirements for most communities will not be incidental and will likely be of sufficient magnitude to necessitate and justify the development of stormwater management programs to generate sustainable revenue sources;
- For any given community, potential costs of implementing the PCPs can vary greatly and will depend largly on the rigor of the up-front planning process. Careful planning

and selection of the best mix of the most cost effective controls based on performance and suitability of applying the controls throughout the community's watershed area will optimize the cost effectiveness of the program and minimize the amount of financial investment needed;

- Stormwater controls effective at reducing phosphorus load should be incorporated into all future re-development and public works projects to the maximum extent possible to make the best use of other funding sources and also reduce overall stormwater management program costs; and
- Reducing stormwater phosphorus loads and other stormwater-related impacts from developed landscapes is expensive and, in the Charles River Watershed, will become the respsonsibility of the municipalities to fund programs to reduce stormwater phosphorus loads. New development and re-development projects need to be required to achive a very high level of stormwater phosphorus load reduction so that these projects do not generate additional financial burden for the commmunities.

(I)Non-Structural Stormwater Phosphorus BMPs

Permittee may satisfy part of its Phosphorus Reduction Requirement by implementing enhanced non-structural BMPs. The enhanced non-structural BMPs are generally of the same kind as the baseline performance BMPs; however, they generally represent a more aggressive degree of control than those defined in Part 2.3 of the Draft Permit.

Regular sweeping, catch basin cleaning, reduced fertilizer use and proper management of landscaping wastes are addressed minimally in the Part 2.3 of the Draft Permit. However, how these controls are applied will determine whether the permittee is allowed to claim credit toward satisfying its phosphorus reduction requirement for the controls. Attachment 2 to Appendix F provides default removal credit factors and acceptable methodologies for calculating removal credits for these controls when implemented as enhanced non-structural BMPs. If the permittee chooses to use enhanced non-structural and structural BMPs to earn phosphorus reduction credits for areas within the watershed of the TMDL waterbody, then the Phosphorus Control Plan (PCP) must include supporting computations for the proposed phosphorus reduction credits. In addition, the controls must be incorporated into the SWMP. The permittee will also need to certify annually in its annual report that the pollution prevention and non-structural BMPs continue to be implemented in order to continue to earn any phosphorus reduction credit from them.

The enhanced non-structural BMPs that a permittee may implement under Appendix F are:

1) Enhanced sweeping of impervious roadways and parking areas;
2) Catch basin cleaning (ensure that no sump is more than 50% full, see part 2.3.7. of the Draft Permit);
3) Elimination of fertilizers containing phosphorus; and
4) Organic waste and leaf litter collection program.

Enhanced sweeping program of impervious roadways and parking areas: The permittee may enhance the sweeping program in Part 2.3.7. of the Draft Permit to earn phosphorus reduction credit for sweeping. To do so, the enhanced program must increase the frequency of sweeping from annually to at least semi-annually. In order to earn credit for semi-annual sweeping the sweeping must occur in the spring following snow-melt and road sand applications to impervious surfaces and in the fall after leaf-fall and prior to the onset to the snow season. With respect to enhanced sweeping, the amount of credit will depend on the frequency of sweeping and the type of sweeping technology used. The methodology for calculating the credit and the default removal factors to calculate the credit are provided in Attachment 2 of Appendix F.

Enhanced sweeping generates a phosphorus reduction credit because more frequent sweeping of impervious surfaces will remove a portion of particulate matter and associated contaminants, such as phosphorus, from impervious surfaces before they can be mobilized by the next rain event. The phosphorus removal credit for enhanced sweeping is a function of the sweeper technology used and the frequency at which the sweeping is performed.

Table 2-2 from Attachment 2 to Appendix F of the Draft Permit (shown below as Table 19), presents the default phosphorus removal factors for calculating phosphorus reduction credits for enhanced sweeping programs. As indicated, the phosphorus removal factors vary according to sweeper type and the frequency of sweeping. For the mechanical brush and vacuum assisted sweeping technologies, EPA is using default factors that were developed by the Center of Watershed Protection (CWP) in fulfillment of an EPA Chesapeake Bay Program grant to develop information on reliable pollutant removal rates for sweeping and catch basin cleaning programs. The findings of this project are presented in the final report entitled *"Deriving Reliable Pollutant Removal Rates for Municipal Street Sweeping and Storm Drain Cleanout programs in the Chesapeake Basin"* and dated September 2008. This CWP project includes an extensive literature review of studies previously conducted to evaluate the pollutant removal effectiveness of sweeping and storm drain cleanout programs. EPA considers the findings from this project to represent sound science based on the currently available information on overall program effectiveness.

Frequency*	**Sweeper Technology**	**PRF** $_{sweeping}$
2/year (spring and fall)	Mechanical Broom	0.01
2/year (spring and fall)	Vacuum Assisted	0.02
2/year (spring and fall)	High-Efficiency Regenerative Air-Vacuum	0.02
Monthly	Mechanical Broom	0.03
Monthly	Vacuum Assisted	0.04
Monthly	High Efficiency Regenerative Air-Vacuum	0.08
Weekly	Mechanical Broom	0.05
Weekly	Vacuum Assisted	0.08
Weekly	High Efficiency Regenerative Air-Vacuum	0.10

Table 19: Table 2-2 of Attachment 2 to appendix F

While the CWP study evaluates a large body of historical information on the effectiveness of sweeping programs, those historical studies did not fully evaluate the latest generation of high-efficiency sweeping technologies. In light of the advancements in sweeping technology, EPA has been exploring the potential effectiveness of high-efficiency sweeping technologies such as the regenerative air street cleaning technology. Recently, a study was conducted in the City of Cambridge, Massachusetts by the U.S. Geological Survey (USGS) in cooperation with Cambridge, Massachusetts Department of Environmental Protection, EPA, and a manufacturer of high-efficiency sweepers to supplement the existing body of information and refine the default phosphorus removal factors previously defined. This study has developed performance information representative of a high-efficiency regenerative air sweeping technology based on pollutant build-up and wash-off data from local conditions within the Charles River watershed and a well-established city sweeping program. The final results of this study were published in 2013, http://pubs.usgs.gov/sir/2012/5292/. Based, in part on data presented in the report, EPA has included default phosphorus removal efficiency factors for the high efficiency regenerative air-vacuum sweeping technology. EPA plans to fully assess the modeling conducted in the USGS study to determine if the selected default credit should be revised.

Sweeper technologies vary in the ability to pick up particulate matter from impervious surfaces. Mechanical broom type sweepers are effective at collecting larger particle sizes and debris while vacuum assisted sweepers and regenerative air sweepers are capable of picking up a wider range of particle sizes including small or finely sized particles that a mechanical broom sweeper would miss. Controlling finely sized particles is crucial to managing phosphorus in storm water runoff, because a large fraction of phosphorus in storm water is often highly associated with the presence of fine particles. As indicated, the vacuum assisted and regenerative air sweeper technologies earn a higher phosphorus removal credits than the mechanical broom sweeper for a given frequency of sweeping.

The frequency at which impervious surfaces are swept affects the overall efficiency of the sweeping program at reducing the phosphorus load in storm water: frequent sweeping will remove a greater pollutant load from impervious surfaces before it can be washed off and discharged to receiving waters. In the metropolitan Boston area, rainfall occurs on average once every three days. This high frequency of rainfall will limit the overall effectiveness of a sweeping program because with each rainfall/runoff event, some portion of the pollutant load is washed-off from impervious surfaces, the amount depending on the intensity and volume of the rainfall. Theoretically, the most effective sweeping program for reducing storm water phosphorus loading would sweep with a high-efficiency sweeper immediately before each rainfall/runoff event. However, such a program has practical limitations. Typically, sweeping programs follow a regular schedule to sweep impervious surfaces (e.g., first Monday of every month).

As indicated in Table 1919, default phosphorus reduction efficiency factors have been developed for semi-annual, monthly and weekly sweeping frequencies. Default efficiency factors for semi-annual sweeping are proposed only for programs in which the sweeping occurs in the spring season following snow-melt to clean road ways of materials deposited during the winter (e.g., sand) and in the fall after leaf-fall and prior to snow-fall. The CWP sweeping efficiency evaluation done for the Chesapeake Bay region did not specify reduction efficiency factors for semi-annual sweeping. However, in New England, timely sweeping during the spring and fall can remove considerable bulk solids that have accumulated during the winter and fall seasons (Sorenson, 2012). Therefore, EPA is proposing default reduction efficiency factors for semi-annual sweeping based on best professional judgment after considering efficiency factors for higher sweeping frequencies and the knowledge of bulk solids accumulations near the end of the winter and fall seasons.

Catch basin cleaning: The permittee may earn a phosphorus reduction credit for cleaning its catch basins such that a minimum sump storage capacity of 50% is maintained throughout the year. Catch basin cleaning must include the removal and proper disposal of recovered materials consistent with local and state requirements. The methodology for calculating the credit and the default removal factors to calculate the credit are provided in Attachment 2 to Appendix F of the Draft Permit.

Catch basins can provide for the capture of limited phosphorus, provided that the available storage capacity in the catch basin sump is sufficient to hold gross particles. Catch basins are most efficient at capturing coarse sediments and debris and are not efficient at capturing finely sized particles with which phosphorus is highly associated.

Table 2-3 from Attachment 2 to Appendix F (shown below as Table 20), presents the default phosphorus removal factor for calculating the phosphorus reduction credit for the required catch basin cleaning program. EPA is using a default factor that was developed by the CWP under the same project cited above. The CWP determined from previous studies that a catch basin will function properly when the sump storage capacity is at least 50% of the total sump capacity. The CWP study estimates that, in general, cleaning a catch basin on a semi-annual basis will be sufficient to maintain this capacity. EPA considers the findings from the CWP project to represent the best currently available information on overall effectiveness of properly maintained catch basins to reduce stormwater phosphorus loading.

Performance Target	Practice	PRF_{CB}
Maintain minimum sump storage capacity $\geq$ 50%	Catch Basin Cleaning	0.02

Table 20: Table 2-3 from attachment 2 to Appendix F

Elimination of unnecessary use of phosphorus-containing fertilizers: The permittee may earn a phosphorus reduction credit by **not** applying phosphorus-containing fertilizers (i.e., “phosphorus free”) to lawn areas from which runoff discharges to the TMDL waterbody. The amount of phosphorus load reduction credit will depend on the amount of lawn area to which no phosphorus-containing fertilizers are applied. Attachment 2 to Appendix F provides the methodology for calculating the phosphorus reduction credit for municipal owned and non-municipal owned lawn areas.

EPA recognizes the potential water quality benefit of limiting the use of phosphorus-containing fertilizer and is proposing a phosphorus reduction credit for use by permittees that will be subject to phosphorus reduction requirements in the Draft Permit. Proposal of this credit coincides with the Commonwealth of Massachusetts’ on-going work to adopt regulations that will reduce the use of phosphorus-containing fertilizers to lawn areas.

Phosphorus in lawn fertilizers is an obvious potential source of phosphorus to receiving waters in urban/suburban areas. There are a number of factors that determine the phosphorus load in storm water from fertilized lawn areas. These factors include the timing of fertilizer applications relative to rain events, application techniques, and the amount of phosphorus in soils relative to plant growth needs. Many lawn areas in New England watersheds do not need phosphorus from fertilizer because soil phosphorus levels typically exceed levels needed to support healthy growth of lawns. Applications of phosphorus-containing fertilizers to such lawns result in the build-up of excessive phosphorus levels in surface soils and, consequently, increased phosphorus transport during runoff events. Studies to quantify the benefits of phosphorus fertilizer control regulations conducted in Ann Arbor, Michigan, and Minnesota indicate that using phosphorus-free fertilizers results in lower phosphorus loading to receiving waters while maintaining healthy lawn growth. However, due to the many variables that affect phosphorus concentrations in receiving waters, including other non-fertilizer sources, it has been difficult to quantify the benefit in terms of reduction credits.

EPA proposes a **reduction factor of 0.50 (i.e., 50% reduction)** to be applied to the average annual phosphorus load export rate from pervious lawn areas that "previously" received phosphorus-containing fertilizers but will no longer receive unnecessary applications of phosphorus-containing fertilizers. The credit applies only to the annual average runoff and associated phosphorus loads from lawn areas. To be eligible for this credit, "previous" phosphorus fertilizer applications means regular fertilizer applications for at least three consecutive years any time after the first day of 1995.

The phosphorus reduction credit has been estimated based on an assessment of stormwater quality data, results of continuous simulation hydrologic modeling using regional climate data, and reported results of studies that investigated phosphorus load reductions associated with phosphorus fertilizer bans. The 0.50 reduction factor was derived by estimating the eventual change in annual mean phosphorus concentration of runoff from lawn areas that would result from no longer receiving regular applications of phosphorus fertilizer (i.e., "fertilized" to "non-fertilized"). It is assumed that the annual runoff volumes of "fertilized" and "non-fertilized" conditions are equivalent because it is hypothesized that adequate phosphorus levels will be maintained in lawn areas to support healthy growth so that runoff conditions will be unchanged.

The proposed reduction factor of 0.5 is based on TP concentrations provided in Table 21. Table 21 presents estimates of nutrient concentrations for "fertilized" and "non-fertilized" lawn areas as represented in the Chesapeake Bay watershed model. These values reflect analysis and evaluation of considerable amounts of information and data from numerous sources that were considered during development of the model. EPA evaluated the representativeness of these estimates by conducting an analysis of stormwater quality data focusing on stormwater total phosphorus (TP) EMC data considered to be representative of runoff from developed lands with rainfall patterns similar to Massachusetts (EPA, 2013). Furthermore, EPA reviewed other evaluations of the benefits of phosphorus fertilizer control regulations to cross-check the Region's approach and results.

Nutrient	TP (mg/L)	TN (mg/L)
Phosphorus Fertilized	0.4	2.5
Phosphorus-free or Non Fertilized	0.2	1.5

Table 21:Suggested EMCs to characterize runoff from lawns (Schueler, 2011)

The reduction factor of 0.5 (i.e., 50%) is equal to the anticipated reduction in the annual mean TP concentration in runoff from lawn areas as a result of applying phosphorus-free fertilizer or not applying fertilizer at all to previously fertilized lawn areas. EPA selected a starting TP value of 0.4 mg/L ("fertilized" in Table 1) and an ending value of 0.2 mg/L ("non-fertilized" in Table 21) to calculate the reduction factor for Massachusetts.

Reduction Factor = (0.4 mg/L – 0.2 mg/L)/ 0.4 = **0.5**

These values were selected for two primary reasons: (1) The robustness of the information used by the Chesapeake Bay Program to derive the estimates in Table 21; and (2) EPA's independent analysis of stormwater quality EMC data, which indicates that these values are of appropriate magnitude for stormwater TP concentrations from pervious areas of developed lands with precipitation patterns similar to Massachusetts.

EPA's stormwater EMC data analysis involved compiling EMC data collected for various land use categories from locations with similar precipitation patterns to Massachusetts (see PLER Memo). The analysis found that median stormwater TP EMCs for large storms (e.g., > 1.0 inches) from residential areas were of similar magnitude to the values in Table 21. Large storm events were specifically analyzed because high precipitation depths increases the potential for pervious area soil saturation and pervious area surface runoff becoming a notable contributor to measured EMCs. Stormwater TP EMC data from residential sites was specifically reviewed because of the relevance of residential lawns to the phosphorus reduction credits in Massachusetts.

To calculate phosphorus load reductions, EPA employed the use of continuous simulation hydrologic models to estimate annual runoff yields for pervious areas and lawn areas specifically with HSGs A, B, C, C/D and D. Hourly and daily temperature records for Boston were used as inputs to the stormwater Management Model (SWMM) and the P8 model to reflect Massachusetts climatic conditions for the Charles River TMDL simulation period (1998-2002). The SWMM and P8 models are both continuous simulation models capable of generating long-term estimates of runoff from pervious areas using long-term climatic records (e.g., hourly precipitation and daily temperature data). SWMM is a process driven mechanistic model that explicitly represents key hydrologic processes such as precipitation, infiltration, and evapo-transpiration. In contrast, the P8 model simulates runoff from pervious areas using the widely used empirical Curve Number Method (CN Method) developed by the Soil Conservation Service (now the Natural Resource Conservation Service, NRCS).

Both models were used for developing average annual runoff yields for lawn areas because each offers strengths in representing varying conditions that exit in the real world. For example, SWMM includes infiltration sub-models that simulate the dynamics of infiltration based on soil conditions and constantly changing percent saturation related to climatic conditions. The CN method is an empirical model that was developed based on extensive observations of runoff from varying surface types (including lawns) and in varying conditions. For this analysis, the simulation results of average annual runoff yields from the two models are provided in Table 22. SWMM was used to generate results for pervious areas with model input infiltration parameters that are representative of HSG A, B, C and D. P8 was used to generate results specifically for pervious lawn areas in "good" and "fair" conditions for HSGs A, B, C and D. Also, averages of the three simulated annual runoff yields for each HSG including the average for C/D as an individual group are included in Table 1722.

Hydrologic Soil Condition (HSG)	**Average Annual Runoff Yield, MG/ha/yr**			
	SWMM Pervious	**CN Method - P8, Grass - Good Condition**	**CN Method - P8, Grass - Fair Condition**	**Overall Average**

A	0.067	0.015	0.042	**0.041**
B	0.210	0.113	0.195	**0.172**
C	0.407	0.278	0.378	**0.354**
C/D	0.547	0.333	0.467	**0.447**
D	0.686	0.387	0.546	**0.540**
MG= Million Gallons, ha = hectare				

Table 172: Average Annual Runoff yields for Pervious Areas by SWMM and Curve Number Method

Consistent with the overall weight of evidence approach taken to develop the phosphorus-free fertilizer reduction credit, EPA used the average of the annual runoff yield results from the three model simulations to calculate the PLERs for each HSG. The PLERs are calculated by multiplying the annual runoff yield by the annual mean concentration of phosphorus for the “fertilized” lawn condition (0.4 mg/L). The calculated PLERs are shown in Table 23. Also shown are the calculated PLERs for the “non-fertilized” lawn condition for each HSG and the difference or estimated reduction in annual phosphorus load from lawns when switching from “fertilized” to “non-fertilized” conditions.

Average Annual phosphorus load Export Rates for Fertilized and Non-fertilized awns				
Cover and Hydrologic Soil Group	**Average Annual Runoff Yield, MG/ha/yr**	**Annual Mean TP Concentration for Lawn Runoff, mg/L**		**phosphorus load Reduction due to Phosphorus free Fertilizer Regulation kg/ha/yr**
		"non-fertilized"	**"fertilized"**	
		0.2	**0.4**	
		Annual phosphorus load Export Rate (PLER), kg/ha/yr		
grass HSG A	0.041	0.03	0.06	0.03
Grass HSG B	0.172	0.13	0.26	0.13
grass HSG C	0.354	0.27	0.54	0.27
grass HSG C/D	0.447	0.34	0.68	0.34
grass HSG D	0.540	0.41	0.82	0.41

Table 183: Average Annual phosphorus load Export Rates for Fertilized and Non-fertilized awns

As indicated in Table 1833, reducing the annual mean TP concentration from 0.4 to 0.2 mg/L (i.e., applying the phosphorus reduction factor of 0.5 to the applicable lawn areas) results in estimated unit area phosphorus load reduction credits of 0.03 to 0.41 kg/ha/yr for lawn areas, depending on hydrologic soil conditions.

Organic waste and leaf litter collection program: The permittee may earn a phosphorus reduction credit by performing proper management and disposal of landscaping wastes, organic debris, and leaf litter at an increased frequency. In order to earn the credit, the permittee must, on a weekly basis between September 1 and December 1 of each year, assure that impervious roadways and parking lots are free of landscaping wastes, organic debris, and leaf litter. The permittee must assure that the disposal of these materials will not contribute pollutants to any surface water. The permittee may use an enhanced sweeping program (e.g., weekly frequency) as a component of the enhanced organic waste/leaf litter collection program, provided that the sweeping targets organic materials. Attachment 2 to Appendix F provides the methodology and default removal factor for calculating the credit.

Organic matter, including grass clippings, leaves and mulch, all contain phosphorus that can be released when saturated with water. As a result, organic matter deposited in drainage system components (e.g., catch basins and structural BMPs) and mobilized to receiving waters during runoff events is likely to become a long-term source of phosphorus. A study investigating sources of phosphorus in two residential basins in Madison, Wisconsin estimated that approximately 30 % of the total phosphorus measured in street dirt samples was from leaf matter. Phosphorus release from decaying matter is intensified under conditions of low dissolved oxygen, which is a common condition in catch basin sumps and certain BMPs such as wet ponds.

EPA considers the transport of organic materials by runoff to be a potential considerable source of phosphorus to the surface waters in New England; activities that prevent these material from entering drainage systems are worthy of a reduction credit. Consequently, EPA is proposing a phosphorus reduction credit of 5% for an organic waste and leaf litter collection program that regularly removes organic matter from impervious surfaces during the leaf fall season. EPA has concluded that a 5% reduction credit for P loading from land areas covered by an organic waste/leaf litter collection program is areasonable default value based on available information.

<u>(J)Structural Stormwater Phosphorus BMPs</u>

The permittee may satisfy its Phosphorus Reduction Requirement in whole or in part by installing and maintaining structural BMPs in the area defined by the permittee. For structural BMP phosphorus load reduction credits, Attachment 3 to Appendix F provides BMP performance information that the permittee may use to calculate the annual phosphorus load reduction for each structural BMP identified in its PCP. In Attachment 3, EPA provides guidelines for selecting which BMP performance information should apply to various BMP categories.

Background on EPA's proposed BMP credits: EPA in cooperation with others conducted two storm water management modeling analyses to better understand appropriate phosphorus reduction credits for structural stormwater controls and potential strategies for most cost-effectively achieving required phosphorus load reductions to impaired waters. These analyses are: 1) *Storm Water Best Management Practices (BMP) Performance Analysis*, Tetra Tech, Inc., December 2008 (revised March 2010); and 2) *Optimal stormwater Management Plan Alternatives: A Demonstration Project in Three Upper Charles River Communities*, Tetra Tech, Inc., December 2009.

The first analysis developed information and estimates of the long-term cumulative performances of several types of structural BMPs for removing phosphorus from stormwater runoff from developed areas, assuming regional rainfall patterns. Long-term cumulative performance estimates, expressed as percent reduction of the long-term pollutant loading to the BMP were developed using calibrated models for a wide range of design capacities in terms of depth (inches) of runoff from contributing IA (0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5 ad 2.0 inches). The results were used to develop performance curves for each of the structural BMPs, which can be used to provide performance estimates for any sized BMP between 0.1 and 2.0 inches of runoff from IA. The BMP performance models used in this analysis were calibrated to BMP performance data collected at the University of New Hampshire's stormwater Center (UNHSWC).

The retrofitting of effective structural stormwater controls into existing developed landscapes presents a number of technical challenges. Among these challenges, space limitation is often considered to be a key factor in determining overall feasibility of installing practices. EPA invested in the BMP performance study to derive credible estimates of pollutant reduction credits for a wide range of BMP capacities because EPA recognizes that the use of small capacity BMPs will increase technical feasibility and the overall cost effectiveness of treating stormwater runoff from developed lands. Furthermore, based on modeling analyses conducted as part of the Lower Charles phosphorus TMDL, certain types of small capacity controls, especially infiltration practices, were estimated to achieve high pollutant reductions. Therefore, EPA determined it necessary to provide credible estimates of phosphorus load reduction credits for commonly used and effective BMPs for a wide range of design capacities to provide permittees with the knowledge to understand the scope of control needed and develop cost effective stormwater management programs.

The second analysis, "the optimization analysis," involved developing optimized storm water management strategies for Milford, Bellingham, and Franklin, Massachusetts. The analysis considered land use, soil conditions, imperviousness, space limitations, topography, depths to groundwater and bedrock, BMP efficiencies, and BMP costs to develop the best approach to the storm water management in those municipalities. The results provide an estimate of the total amount of phosphorus control, expressed in terms of BMP type, BMP capacity, and drainage area to be treated necessary to meet the Charles River Phosphorus TMDL reductions.

Key findings from these two analyses include the following:

- BMP performance for capturing phosphorus varies considerably depending on BMP type and design capacity. Infiltration systems have the highest phosphorus removal efficiencies and can achieve high phosphorus capture rates even for small sized systems. For example, a surface infiltration system designed with a half inch (0.5) of storage capacity can achieve estimated phosphorus removal efficiencies of between 76% and 97%, depending on the infiltration rate of the subsurface soil. BMPs that include a filtering medium such as bioretention/filtration systems, gravel wetlands, and porous pavement are the next best performers for removing phosphorus. Such BMP systems sized for storing a half inch (0.5) of runoff are estimated to achieve long-term phosphorus removal rates of between 46% and 55%, respectively. BMPs such as detention basins that rely mostly on the settling of particulate matter to remove pollutants have the poorest performance rates. For example, phosphorus removal efficiencies for dry detention ponds are estimated to level off at 15%, even for large capacity systems sized for 2.0 inches of runoff.

- With respect to long-term cumulative phosphorus removal, the performance of infiltration BMPs treating impervious runoff noticeably levels off when the BMP storage capacity exceeds approximately 1.0 inch of runoff. This is because much of the pollutant load available for wash-off from impervious surfaces is mobilized during the frequently occurring small sized rain events and during the early phases of less frequently occurring large rain events. In other words, an infiltration system sized for one inch of runoff will capture most of the phosphorus load that is cumulatively washed off of impervious surfaces over a long period of time.

A program aimed at optimizing phosphorus reduction strategies across a municipality will favor a management approach that maximizes the use of the most effective BMPs (e.g., infiltration practices), installs these BMPs in areas where site conditions are favorable for their use (e.g. permeable soils that will provide for phosphorus adhesion) and positions them where runoff from high phosphorus loading areas (e.g., impervious surfaces) can be captured and treated. Such a program will also size the BMPs for these optimal locations in order to most effectively capture phosphorus and achieve high removal efficiencies (e.g., 80-90%) if space allows. Optimizing the type, sizing, and placement of BMPs throughout a municipality as part of an overall comprehensive management plans will deliver the greatest amount of phosphorus load reduction for the least cost.

Infiltration is among the most effective stormwater BMPs for controlling phosphorus and bacteria in stormwater runoff. Additionally, infiltration practices offer numerous other benefits including ground water recharge, peak runoff rate attenuation, reduced thermal impacts to receiving waters, and enhanced base flow to local streams. In short, properly placed and installed infiltration BMPs will address many aspects of water quality degradation caused by stormwater runoff from developed sites.

No particular non-structural or structural BMP is required of a permittee. EPA is interested in expanding and refining the available credits for phosphorous reduction gained through implementation of non-structural and structural BMPs. EPA believes providing and refining phosphorus reduction credits from non-structural and structural BMPs to be an on-going process and plans to update reduction credits as scientifically valid long term studies of BMP efficiencies or performance are completed and the results are reviewed by EPA staff for applicability.

Stormwater Phosphorus Loads to Structural BMPs: In order to calculate phosphorus load reduction credits for planned non-structural and structural BMPs, it is first necessary to estimate stormwater phosphorus load for the watershed drainage area that will receive treatment or application of BMPs. The Permittee is given distinct PLERs in Attachments 2 and 3 to Appendix F to calculate stormwater phosphorus loads to be treated by BMPs. The estimates of stormwater phosphorus load reductions by BMPs will be used by the permittee to demonstrate compliance with the phosphorus load reduction requirement of the Draft Permit. The estimates will also allow EPA, MassDEP and the municipality to track progress towards achieving the overall stormwater phosphorus load reduction requirement in the permit and consistent with the waste load allocations established in the TMDLs. EPA feels it is necessary and a more robust approach to break down phosphorus export rates by pervious and impervious area by land use type when calculating BMP performance. Greater accuracy in load estimation is needed for proper accounting of loading to specific BMPs, as opposed to generalized composite loading rates that are appropriate for watershed analysis where the level of detail of drainage area is not known.

The PLERs presented in Tables 2-1 and 3-1 of Attachments 2 and 3 to Appendix F, respectively and shown below represent estimates of the average annual stormwater phosphorus load that would be delivered from impervious and pervious surfaces for nine (9) land use categories (commercial and industrial are grouped together). The nine land use categories identified in Table 24 represent aggregated land use groups made up of land use categories identified by MassGIS and grouped according to similarities in terms of generating phosphorus loads.

These PLERs estimate the relative magnitude of phosphorus loads from impervious and pervious surfaces for each of the land use groups. Separate or distinct PLERs for impervious and pervious surface are provided to improve the accounting of phosphorus reduction credits for individual BMPs. In many cases BMPs are targeted to address runoff from primarily impervious surfaces. As indicated,, the PLERs for impervious surface for the various land use groupings are notably higher than their corresponding pervious PLERs. This is primarily due to the fact that impervious surfaces generate greater volumes of runoff than pervious surfaces and because phosphorus is more readily washed off of impervious surface than pervious surfaces.

The PLERs presented in Table 24 have been developed based on detailed analyses of the following information:

- stormwater quality data from the National stormwater Quality Database (NSQD, 2008) for rainfall Regions 1 and 2;
- Various stormwater quality datasets collected in New England (many sources);
- Hydrologic Response Unit (HRU) Modeling: Results of long-term (5 year) continuous hydrologic model simulations using the stormwater Management Model (SWMM) and P8 Model (Curve Number Method) that are representative of local climatic conditions (hourly precipitation and daily temperature). These models were applied to watershed areas with homogeneous land characteristics relating to surface type (impervious or pervious), hydrologic soil condition (e.g., hydrological soil groups A, B, C and D) and vegetative cover (e.g., grass or forested).
- Various stormwater/watershed modeling efforts including the following pollutant loading analyses:
    - Streamflow, Water Quality, and Contaminant Loads in the Lower Charles River Watershed, Massachusetts, 1999-2000, Breault, et al., 2002;
    - *Measured and Simulated Runoff to the Lower Charles River, Massachusetts, October 1999–September 2000*, Zariello and Barlow, 2002;
    - Calibration of Phosphorus Export Coefficients for Total Maximum Daily Loads of Massachusetts Lakes, Mattson and Isaac, 1999;
    - Optimal Stormwater Management Plan Alternatives: A Demonstration Project in Three Upper Charles River Communities, Tetra Tech, Inc., December 2009;
    - Updating the Lake Champlain Basin Land Use Data to Improve Prediction of Phosphorus Loading, Troy, et al., 2007;
    - Literature Review of Phosphorus Export Rates and Best Management Practices, LaPlatte River Watershed Project, Artuso, et al., 1996;
    - Lake Champlain Nonpoint Source Pollution Assessment, Budd and Meals, 1994; and
- Literature values from various sources including the Fundamentals of Urban Runoff Management, (Shaver, et al., 2007); Review of Published Export Coefficient and Event Mean Concentration Data (Lin, 1994); and the Draft Chesapeake stormwater Network (CSN) Technical Bulletin No. 9, Nutrient Accounting Methods to Document Local stormwater Load Reductions in the Chesapeake Bay Watershed, Version 1.0, (Schueler, 2011);
- Data collected by the USGS in the study of Potential Reductions of Phosphorus in Urban Watershed using a High-Efficiency Street-Cleaning Program, Cambridge, Massachusetts, Sorenson, 2011; and

- Sutherland models to estimate directly connected impervious area from total impervious area.

In summary, the PLERs presented in Table 24 were developed based on a weight of evidence approach summarized below. Table 194 also provides a brief description of the basis used to develop the land use based PLERs.

- Representative stormwater quality event mean concentration (EMC) data were compiled and reviewed to determine phosphorus characteristics and relative differences among land use source types. This process was used to aid identification of appropriate groupings of land use categories for characterizing phosphorus Loadings, to determine the relative strength of phosphorus loading among the various land use groups and to determine the typical magnitude of phosphorus concentrations in stormwater runoff from developed lands.
- Hydrologic Response Unit modeling was conducted to estimate average annual runoff yields and corresponding average annual PLERs for varying stormwater phosphorus quality based on land surface type, hydrologic soil condition, vegetative cover and regional climatic conditions. The HRU modeling result assists in developing the linkage between stormwater monitoring results that measured EMCs (mg/L) for many individual storm events and average annual PLERs (kg/ha/yr);
- For certain categories such as forested, agricultural sources and rural/open space type sources, estimates of PLERs are based both directly and indirectly on reported values from published papers and reports. For example, the PLERs for low density residential, highway and forested are based in part on reported "composite" PLERs values (i.e., represent combined influence of areas with both impervious and pervious surfaces) and subsequent HRU modeling to estimate the individual PLERs for impervious and pervious surface within that source category. For example, the composite PLER for forested (For) of 0.13 kg/ha/yr (Mattson and Isaac, 1999) was used as a starting point and then refined further into distinct PLERs for DCIA and PA by using continuous simulation hydrologic modeling with regional climatic data, estimated % DCIA, average % impervious associated with forested, and a typical pervious runoff total phosphorus (TP) concentration (0.1 mg/L) to estimate PLERs of 1.7 kg/ha/yr for impervious surfaces and 0.13 kg/ha/yr for pervious areas.
- Various pollutant loading studies were evaluated in combination with the HRU modeling results to assist in developing the relationship between source category phosphorus EMC data and annual loading rates. The USGS pollutant load study for the Lower Charles River, MA (Breault, et al, 2002) provides relevant information in that it included extensive flow and quality monitoring data for each of three land use categories, medium density residential, multi-family residential and commercial. Additionally, the USGS developed and calibrated hydrologic (SWMM) models of these drainages and estimated annual phosphorus loads for the year-long flow-gauging and monitoring period. EPA used HRU modeling results in combination with the USGS data and the robust NSQD dataset to estimate impervious and pervious PLERs for these land use groupings.
- For all source categories included in Table 1, EPA cross-checked various sources of information to ensure that the proposed PLERs are in reasonable agreement with other reported information related to phosphorus loading.

Again, the distinct PLERs in Table 1944 are for permittees to estimate load reduction credits for BMPs treating runoff from varying land uses and to provide a consistent accounting methodology that would be applicable for all municipalities within a given watershed.

Ultimately, the calculated reductions based on the provided PLERs are for a permittee to demonstrate compliance with the phosphorus load reduction requirement for their regulated area.

Phosphorus Source Category by Land Use	Land Surface Cover	Phosphorus load Export Rate, Kg/ha/yr	Comments
Commercial (Com) and Industrial (Ind)	Directly connected impervious	2.0	Derived using a combination of the Lower Charles USGS loads study and NSWQ dataset. This PLER is approximately 75% of the HDR PLER and reflects the difference in the distributions of stormwater TP EMCs between Commercial/Industrial and Residential.
	Pervious	See* DevPERV	
Multi-Family (MFR) and High-Density Residential (HDR)	Directly connected impervious	2.6	Largely based on loading information from Charles USGS loads, SWMM HRU modeling, and NSWQ data set
	Pervious	See* DevPERV	
Medium -Density Residential (MDR)	Directly connected impervious	2.2	Largely based on loading information from Charles USGS loads, SWMM HRU modeling, and NSWQ data set
	Pervious	See* DevPERV	
Low Density Residential (LDR) - "Rural"	Directly connected impervious	1.7	Derived in part from Mattson Issac, HRU modeling, lawn runoff TP quality information from Chesapeake Bay and subsequent modeling to estimate PLER for DCIA (Table 14) to approximate literature reported composite rate 0.3 kg/ha/yr.
	Pervious	See* DevPERV	
Highway (HWY)	Directly connected impervious	1.5	Largely based on USGS highway runoff data, HRU modeling, information from Shaver et al and subsequent modeling to estimate PLER for DCIA for literature reported composite rate 0.9 kg/ha/yr.
	Pervious	See* DevPERV	
Forest (For)	Directly connected impervious	1.7	Derived from Mattson & Issac and subsequent modeling to estimate PLER for DCIA that corresponds with the literature reported composite rate of 0.13 kg/ha/yr (Table 14)
	Pervious	0.13	
Open Land (Open)	Directly connected impervious	1.7	Derived in part from Mattson Issac, HRU modeling, lawn runoff TP quality information from Chesapeake Bay and subsequent modeling to estimate PLER for DCIA (Table 14) to approximate literature reported composite rate 0.3 kg/ha/yr.
	Pervious	See* DevPERV	
Agriculture (Ag)	Directly connected impervious	1.7	Derived from Budd, L.F. and D.W. Meals and subsequent modeling to estimate PLER for DCIA to approximate reported composite PLER of 0.5 kg/ha/yr.
	Pervious	0.5	
*Developed Land Pervious (DevPERV)- Hydrologic Soil Group A	Pervious	0.03	Derived from SWMM and P8 - Curve Number continuous simulation HRU modeling with assumed TP concentration of 0.2 mg/L for pervious runoff from developed lands. TP of 0.2 mg/L is based on TB-9 (CSN, 2011), and other PLER literature and assumes unfertilized condition due to the upcoming MA phosphorus fertilizer control legislation.
*Developed Land Pervious (DevPERV)- Hydrologic Soil Group B	Pervious	0.13	
*Developed Land Pervious (DevPERV) - Hydrologic Soil Group C	Pervious	0.24	
*Developed Land Pervious (DevPERV) - Hydrologic Soil Group C/D	Pervious	0.33	
*Developed Land Pervious (DevPERV) - Hydrologic Soil Group D	Pervious	0.41	

Table 194: Proposed average annual distinct phosphorus load export rates for use in estimating phosphorus load reduction credits the MA MS4 Permit

(K) Phosphorus Loading Associated with New Development

Table 1-1 in Attachment 1 to Appendix F of the permit presents the Composite PLERs to be used by permittees to calculate phosphorus load increases associated with development. These composite rates will also be used by those permittees subject to phosphorus reduction requirements based on EPA approved phosphorus TMDLs other than the Charles Rivers phosphorus TMDLs (lake and Pond phosphorus TMDLs) to calculate baseline phosphorus loads. The composite PLERs represent estimates of the average annual phosphorus load that would be delivered from the combination of impervious and pervious surfaces for nine (9) land use categories.
The nine land use categories identified in Table 1-1 in Attachment 1 to Appendix F represent aggregated land use categories made up of land use categories identified by MassGIS and grouped according to similarities in terms of generating phosphorus loads. Appendix A to this attachment provides the cross walk between the MassGIS land uses and the land use categories used for calculating phosphorus loading in Table 1-1 in Attachment 1 to Appendix F.

Methodology:
The export rates presented in Table 1-1 in Attachment 1 to Appendix F have been developed using the distinct PLERs described in above in Section J of the Charles River TMDL portion of this fact sheet, estimates of average total impervious area (TIA) for each of the land use category and estimates of directly connected impervious area (DCIA) based on the Sutherland equations.

Composite PLER = ((% DCIA/100) x DCIA PLER) + ((100 -%DCIA)/100) x PA-PLER)

Land Cover	Representative Total Impervious Area Percentage, %	Sutherland Eqt. Used To Estimate Directly Connected Impervious Area (DCIA)	Sutherland DCIA eqt. description	Estimated DCIA, %	DCIA PLER, kg/ha/yr	Weighted Average Pervious Area PLER*, kg /ha/yr	Calculated composite PLER, kg/ha/yr PLER=((%DCIA/100)xDCIA-PLER)+(((100-%DCIA)/100)x PA-PLER)	Composite Literature reported Phosphorus Export Loading Rates (kg/ha/yr)	Proposed Composite PLERs for Calculating Base Line Phosphorus Load for MA MS4, kg/ha/yr
Commercial	62	**DCIA=0.4(TIA)$^{1.2}$**	Highly Connected	56.6	2.00	0.38	1.30	1.679 (1)	**1.30**
Industrial	71	**DCIA=0.4(TIA)$^{1.2}$**	Highly Connected	66.6	2.00	0.35	1.45	1.455 (1)	**1.45**
High Density Residential	42	**DCIA=0.4(TIA)$^{1.2}$**	Highly Connected	35.5	2.60	0.42	1.20	1.12 (1)	**1.20**
Medium Density Residential	29	**DCIA=0.1(TIA)$^{1.5}$**	Average	15.6	2.20	0.33	0.62	0.56 (1)	**0.62**

Low Density Residential	23	**DCIA=0.1(TIA)$^{1.5}$**	Average	11.0	1.70	0.25	0.41	0.30 (2)	**0.41**
Freeway	58	**DCIA=0.1(TIA)$^{1.5}$**	Average	44.2	1.50	0.39	0.88	0.90 (1)	**0.88**
Open Space	19	**DCIA=0.1(TIA)$^{1.5}$**	Average	8.3	1.70	0.25	0.37	0.30 (2)	**0.37**
Agriculture	6	**DCIA=0.01(TIA)$^{2.0}$**	Mostly Disconnected	0.4	1.70	0.43	0.43	0.5(3)	**0.50**
Forest	3	**DCIA=0.01(TIA)$^{2.0}$**	Mostly Disconnected	0.1	1.70	0.14	0.14	0.13 (2)	**0.13**

1. Shaver, E., Horner R., Skupien J., May C., and Ridley G. 2007 Fundamentals of urban runoff management: technical and institutional issues. Prepared by the North American Lake Management Society, Madison, WI, in cooperation with the U.S. Environmental Protection Agency.

2. Mattson, Mark D. and Russell A. Isaac. 1999. *Calibration of phosphorus export coefficients for Total Maximum Daily Loads of Massachusetts's lakes.* Lake Reservoir. Management, 15:209-219.

3. Budd, Lenore F. and Donald W. Meals. February 17, 1994. Draft Final Report. Lake Champlain Nonpoint Pollution Assessment.

Notes:* Weighted average pervious area PLER is based on hydrologic soil distribution by land use in the upper Charles River Watershed (CRW) upstream of Watertown Dam, HRU modeling runoff yield results for HSG groups and annual mean TP concentrations of 0.3 mg/L for all LU categories except Ag and For where TP concentrations of 0.5 mg/L and 0.1 mg/l were used, respectively.

Table 25 presents the values of TIA (column 2), DCIA (column 5), DCIA-PLER (column 6) and PA-PLER (column 7) used to estimate the composite PLER (column 8) for each land use category. Also shown are literature reported composite PLERs (column 9) and recommended PLERS (column 10) for use in the Massachusetts MS4 permitting process (excluding the Charles River watershed). Composite PLERs are calculated using the following equation:

Table 25: Calculated and Recommended Composite PLERs based on TIA, DCIA, and Distinct PLERs

The distinct PLERS for DCIA and PA are used to calculate composite PLERs. Pervious area PLERs vary by land use category based on the distribution of HSGs within the land use category. These values were calculated using the HRU modeling runoff yield results, the HSG distribution by land use category observed in the Upper Charles River watershed (upstream of Watertown Dam) and annual mean phosphorus concentration of 0.3 mg/L for PA runoff for all land use categories except forested and agriculture, 0.1 mg/L for Forest and 0.5 mg/l for Agriculture.

> The average % TIA and distribution of HSGs by land use category from the Upper Charles River watershed are being used to represent conditions in other watersheds with urban areas tributary to phosphorus TMDL waterbodies. Currently, the MS4 drainage areas are not available to estimate actual % TIA and HSG distribution by land use for each MS4. Since much of the Upper Charles River watershed is designated as an urban area it is assumed that average % TIA and HSG distribution for the land use categories are reasonable approximations for calculating composite PLERs to be used by the MS4 for their urban areas.

A comparison of the calculated composite PLERs (column 8) and the literature reported composite PLERs (column 9) indicate that the corresponding values are of similar magnitude. As indicated in Table 25, the calculated composite PLERs for all land use categories except Forest and Agriculture are proposed for use in the Massachusetts MS4 permitting process. The recommended composite PLERs for the Forest and Agriculture categories are based on the reported literature rates.

The composite phosphorus loading rates for use in calculating phosphorus loading rate increases due to development will differ slightly from those composite rates used to calculate the baseline phosphorus loading for Charles River watershed communities. This is due to the fact that the baseline rates were calibrated to past data used in TMDL development. Moving forward, EPA feels it is appropriate that new development be treated equally across the Charles River watershed for purposes of accounting and the composite loading rate approach streamlines and provides uniformity to the process. While non-composite rates are used to estimate BMP performance, this level of detail is not warranted for calculation of new development loads as the specificity of information available when sizing a structural BMP will not always be available when calculating load increases from larger land areas associated with development or land use change. Although these composite rates were calculated for the Charles River communities EPA feels that the varied land use and development patterns throughout the Charles River watershed make these values applicable regionally and therefore these values will also be used to calculate baseline phosphorus loading from regulated area discharging to a waterbody with a lake or pond TMDL, or its tributaries.

ATTACHMENT A

Crosswalk MassGIS Land Use to Land Use Groups for Phosphorus load Calculations

Mass GIS Land Use LU_CODE	Description	Land Use group for calculating Phosphorus Load - 2013/14 MA MS4
1	Crop Land	Agriculture
2	Pasture (active)	Agriculture
3	Forest	Forest
4	Wetland	Forest
5	Mining	Industrial
6	Open Land includes inactive pasture	open land
7	Participation Recreation	open land
8	spectator recreation	open land
9	Water Based Recreation	open land
10	Multi-Family Residential	High Density Residential
11	High Density Residential	High Density Residential
12	Medium Density Residential	Medium Density Residential
13	Low Density Residential	Low Density Residential
14	Saltwater Wetland	Water
15	Commercial	Commercial
16	Industrial	Industrial
17	Urban Open	open land
18	Transportation	Highway
19	Waste Disposal	Industrial
20	Water	Water
23	cranberry bog	Agriculture
24	Powerline	open land
25	Saltwater Sandy Beach	open land
26	Golf Course	Agriculture
29	Marina	Commercial
31	Urban Public	Commercial
34	Cemetery	open land
35	Orchard	Forest
36	Nursery	Agriculture
37	Forested Wetland	Forest
38	Very Low Density residential	Low Density Residential
39	Junkyards	Industrial
40	Brush land/Successional	Forest

Attachment 1- Fact Sheet Massachusetts Small MS4

ATTACHMENT B

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Excluding land use areas in communities that total less than 5 acres										
Percent Total Impervious Area (TIA) Cover of aggregate land use categories in the Charles River Watershed										
Community	**Commercial**	**Industrial**	**High Density Residential**	**Medium Density Residential**	**Low Density Residential**	**Highway**	**open land**	**Agriculture**	**Forest**	**overall %TIA**
Arlington	59.9%		43.4%			83.6%	34.1%		4.2%	**45.0%**
Ashland			33.7%	26.1%	26.3%			3.4%	1.8%	**12.2%**
Bellingham	68.8%	72.7%	32.6%	26.0%	23.7%	49.3%	16.3%	4.7%	1.9%	**14.7%**
Belmont	48.5%	31.5%	42.1%	32.0%	37.1%	85.6%	24.9%	7.1%	4.4%	**21.8%**
Boston	72.6%	81.9%	57.5%	32.3%	30.9%	87.8%	27.1%	10.6%	8.1%	**48.3%**
Brookline	70.1%	68.4%	56.1%	33.4%	28.3%	82.9%	24.2%	8.7%	8.6%	**39.0%**
Cambridge	77.6%	93.2%	68.4%	38.1%		92.2%	29.6%		10.1%	**51.2%**
Dedham	66.7%	87.3%	38.9%	29.9%	23.1%	60.9%	27.7%	1.9%	2.5%	**19.8%**
DoverU	47.3%			29.4%	21.7%	7.2%	11.8%	5.2%	1.8%	**6.8%**
Foxborough									2.3%	**12.1%**
Franklin	66.6%	69.0%	38.7%	26.4%	23.1%	56.5%	20.7%	5.6%	2.2%	**15.2%**
Holliston	53.1%	55.6%	32.3%	24.4%	21.2%		14.5%	5.7%	1.7%	**9.7%**
Hopedale	56.2%	80.6%		27.5%	24.2%		13.9%		2.3%	**17.1%**
Hopkinton	61.3%	71.9%	30.3%	22.0%	22.7%	32.5%	42.6%	16.6%	1.9%	**10.8%**
Lexington	55.0%	57.9%	37.5%	28.4%	25.7%	60.7%	9.4%	8.2%	2.8%	**19.2%**
Lincoln	51.4%		33.3%		23.3%	73.3%	9.6%	2.7%	3.4%	**7.4%**
Medfield	59.8%	52.6%	34.8%	28.5%	25.5%	45.4%	14.2%	5.3%	1.8%	**11.4%**
Medway	65.0%	58.8%	33.4%	26.2%	22.4%	34.2%	14.6%	7.7%	2.1%	**13.1%**
Mendon	76.3%	69.9%			26.7%		5.2%	2.8%	1.6%	**14.3%**
Milford	76.0%	75.7%	40.3%	27.6%	24.9%	40.1%	25.0%	7.5%	3.1%	**21.1%**
Millis	66.6%	76.8%	37.6%	23.1%	19.3%	52.2%	17.3%	5.7%	1.5%	**9.0%**
Natick	63.5%	68.9%	37.8%	29.2%	23.9%	65.1%	19.1%	7.9%	2.4%	**15.7%**
Needham	67.5%	80.5%	34.7%	32.6%	23.2%	62.0%	17.0%	6.4%	2.3%	**23.0%**
Newton	67.8%	77.3%	44.1%	33.8%	23.6%	75.5%	20.2%	7.0%	4.5%	**35.3%**
Norfolk	52.7%	59.8%	45.2%	23.6%	21.8%	26.4%	20.2%	11.2%	2.3%	**9.5%**
Somerville	84.9%	95.1%	74.0%			95.7%	43.3%			**82.4%**
Sherborn	43.1%	61.4%	30.8%		18.9%	60.3%	9.2%	3.8%	2.2%	**5.2%**
Walpole	56.4%			34.7%	24.3%		14.6%	3.5%	2.2%	**8.5%**
Waltham	64.0%	75.8%	47.6%	32.9%	28.6%	67.9%	30.0%	10.1%	4.3%	**36.1%**
Watertown	74.6%	82.7%	48.9%			53.2%	21.4%	4.7%	10.7%	**49.3%**
Wayland			44.2%	29.2%	27.5%	63.9%	7.9%		4.7%	**17.1%**
Wellesley	51.5%		41.8%	30.1%	30.5%	69.8%	19.5%	6.2%	4.6%	**24.6%**
Weston	52.6%	40.6%	35.2%	24.6%	25.3%	69.7%	18.3%	6.9%	3.9%	**13.3%**
Westwood	51.6%	70.6%	41.9%	23.8%	20.3%	63.7%	16.3%	6.0%	2.7%	**13.6%**
Wrentham	60.9%	84.4%	33.3%	26.7%	24.6%	53.6%	22.7%	12.2%	2.3%	**11.5%**
indicates <5 acres										
Charles River Watershed (exc. CSA)	**66.1%**	**73.3%**	**48.6%**	**28.9%**	**23.1%**	**65.8%**	**21.3%**	**6.4%**	**2.6%**	**20.1%**
Distribution of percent total impervious area (TIA) by Land Use for communities in the Charles River watershed										
average	**62.2%**	**70.4%**	**41.7%**	**28.7%**	**24.7%**	**61.1%**	**20.1%**	**6.7%**	**3.5%**	**21.8%**
median	**62.4%**	**71.9%**	**38.8%**	**28.4%**	**24.0%**	**62.0%**	**19.1%**	**6.2%**	**2.4%**	**15.2%**
low	43.1%	31.5%	30.3%	22.0%	18.9%	7.2%	5.2%	1.9%	1.5%	5.2%
high	84.9%	95.1%	74.0%	38.1%	37.1%	95.7%	43.3%	16.6%	10.7%	82.4%
1st quartile	**52.8%**	**59.8%**	**33.7%**	**26.0%**	**22.6%**	**50.8%**	**14.3%**	**4.7%**	**2.0%**	**11.4%**
3rd quartile	**68.6%**	**80.6%**	**44.4%**	**32.2%**	**26.4%**	**74.4%**	**24.9%**	**8.1%**	**4.4%**	**24.6%**
	Commercial	**Industrial**	**High Density Residential**	**Medium Density Residential**	**Low Density Residential**	**Highway**	**open land**	**Agriculture**	**Forest**	**All**

Area of aggregate land use categories in the entire Charles River Watershed, hectares (ha) (excludes combined sewer area)										
Community	Commercial	Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Highway	open land	Agriculture	Forest	Total
Arlington_MA	5.8	0.0	84.8	0.0	0.0	5.3	4.1	0.0	2.6	102.6
Ashland_MA	1.4	0.7	16.1	31.6	12.6	0.0	1.1	7.9	92.8	164.2
Bellingham_MA	97.6	132.3	152.7	138.3	164.6	66.3	129.8	47.4	1547.8	2476.8
Belmont_MA	30.1	6.8	72.0	25.9	14.3	3.6	2.5	62.3	118.9	336.5
Boston_MA	1230.7	147.7	2540.5	44.6	10.4	235.7	690.6	102.6	913.2	5915.9
Brookline_MA	198.4	8.0	609.2	184.5	215.9	23.0	117.1	128.4	264.5	1749.1
Cambridge_MA	117.1	25.8	150.5	15.4	1.3	18.2	62.2	0.0	4.4	394.9
Dedham_MA	195.5	22.8	80.2	325.4	125.5	44.9	75.0	39.6	937.0	1845.8
Dover_MA	46.5	0.0	0.0	13.9	640.0	6.8	65.7	220.6	2298.2	3291.7
Foxborough_MA	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	3.8	5.3
Franklin_MA	175.9	270.5	143.2	871.0	801.6	105.8	253.5	183.4	3527.3	6332.1
Holliston_MA	87.3	155.1	53.0	458.0	612.3	0.7	134.4	160.2	3165.9	4826.9
Hopedale_MA	10.1	16.3	0.0	45.5	46.4	1.7	6.0	0.9	154.6	281.5
Hopkinton_MA	4.1	21.9	10.1	5.4	240.6	12.7	12.2	3.1	555.2	865.1
Lexington_MA	111.7	18.6	47.4	197.0	103.9	85.5	48.6	41.6	608.6	1262.9
Lincoln_MA	29.6	1.2	14.8	0.1	351.6	8.9	46.6	160.2	1603.4	2216.4
Medfield_MA	84.5	37.2	62.3	357.0	331.4	14.1	75.2	104.4	1837.6	2903.6
Medway_MA	77.1	52.1	107.7	160.3	733.6	3.1	170.3	150.6	1525.0	2979.9
Mendon_MA	5.2	4.6	0.7	0.0	12.1	0.0	2.7	4.7	51.2	81.1
Milford_MA	151.2	175.1	283.6	578.7	181.4	96.7	187.8	6.7	1616.4	3277.6
Millis_MA	47.3	68.1	35.1	240.3	342.8	8.4	75.5	304.6	1994.7	3116.8
Natick_MA	101.4	19.8	176.0	306.4	428.4	13.4	67.0	146.1	1211.7	2470.3
Needham_MA	156.5	124.7	655.2	451.4	357.7	69.7	107.8	67.3	1201.1	3191.4
Newton_MA	468.3	58.4	1770.8	971.6	93.7	113.0	203.3	197.3	740.2	4616.7
Norfolk_MA	87.9	35.1	11.1	254.0	557.3	49.2	169.6	135.9	2569.2	3869.2
Somerville_MA	81.5	75.2	159.1	0.0	0.0	44.8	10.6	0.0	0.0	371.3
Sherborn_MA	21.9	3.5	6.3	0.7	452.0	6.4	57.0	276.1	2406.8	3230.8
Walpole_MA	11.6	0.0	0.1	5.1	109.4	1.8	18.3	17.2	405.9	569.5
Waltham_MA	621.6	234.4	1038.0	220.4	22.2	71.0	143.2	31.2	907.7	3289.7
Watertown_MA	215.4	66.7	491.1	0.0	0.0	4.7	117.5	25.1	29.6	950.3
Wayland_MA	0.0	0.3	9.5	22.6	10.7	9.3	2.1	0.5	83.5	138.5
Wellesley_MA	371.4	0.7	145.7	1040.9	66.9	34.2	79.8	77.2	774.3	2591.1
Weston_MA	117.9	29.1	25.7	89.2	973.7	91.0	125.6	215.5	2298.9	3966.5
Westwood_MA	49.4	3.2	5.3	121.7	216.7	16.0	25.5	56.3	464.6	958.5
Wrentham_MA	68.4	77.0	18.9	73.9	286.5	34.8	82.5	35.1	1585.5	2262.6
										76903.4

Impervious Area of aggregate land use categories in the Charles River Watershed, hectares (ha) -excludes combined sewer area										
Community	Commercial	Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Highway	open land	Agriculture	Forest	Total
Arlington_MA	3.5	0.0	36.8	0.0	0.0	4.4	1.4	0.0	0.1	46.2
Ashland_MA	0.6	0.2	5.4	8.3	3.3	0.0	0.4	0.3	1.6	20.1
Bellingham_MA	67.2	96.2	49.8	36.0	39.0	32.7	21.1	2.2	29.0	373.1
Belmont_MA	14.6	2.2	30.3	8.3	5.3	3.1	0.6	4.4	5.3	74.1
Boston_MA	893.3	121.0	1460.1	14.4	3.2	206.9	187.4	10.9	73.8	2970.9
Brookline_MA	139.1	5.5	341.5	61.6	61.1	19.1	28.3	11.2	22.6	690.1
Cambridge_MA	90.8	24.0	102.9	5.9	0.3	16.8	18.4	0.0	0.4	259.6
Dedham_MA	130.5	19.9	31.2	97.4	29.0	27.3	20.8	0.7	23.1	379.9
Dover_MA	22.0	0.0	0.0	4.1	138.7	0.5	7.8	11.4	41.0	225.4
Foxborough_MA	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.1	0.6
Franklin_MA	117.2	186.6	55.4	230.1	184.9	59.8	52.3	10.4	76.3	972.9
Holliston_MA	46.4	86.1	17.1	111.6	129.6	0.4	19.5	9.2	53.9	473.8
Hopedale_MA	5.7	13.2	0.0	12.5	11.2	0.9	0.8	0.1	3.6	48.0
Hopkinton_MA	2.5	15.8	3.0	1.2	54.6	4.1	5.2	0.5	10.8	97.7
Lexington_MA	61.4	10.8	17.8	55.9	26.7	51.9	4.5	3.4	17.1	249.6
Lincoln_MA	15.2	0.8	4.9	0.0	82.0	6.5	4.5	4.4	55.2	173.5
Medfield_MA	50.6	19.6	21.7	101.7	84.5	6.4	10.7	5.5	33.3	333.9
Medway_MA	50.1	30.6	36.0	41.9	164.4	1.1	24.8	11.6	31.4	392.0
Mendon_MA	3.9	3.2	0.4	0.0	3.2	0.0	0.1	0.1	0.8	11.8
Milford_MA	115.0	132.6	114.4	159.6	45.3	38.8	46.9	0.5	50.8	703.8
Millis_MA	31.5	52.3	13.2	55.5	66.3	4.4	13.1	17.3	30.3	283.8
Natick_MA	64.4	13.7	66.6	89.4	102.5	8.7	12.8	11.6	29.0	398.7
Needham_MA	105.6	100.4	227.6	147.3	83.0	43.3	18.3	4.3	27.2	756.8
Newton_MA	317.4	45.1	781.1	328.0	22.1	85.3	41.1	13.7	33.2	1667.1
Norfolk_MA	46.3	21.0	5.0	59.9	121.4	13.0	34.3	15.3	60.0	376.2
Somerville_MA	69.2	71.6	117.7	0.0	0.0	42.9	4.6	0.0	0.0	306.0
Sherborn_MA	9.4	2.2	1.9	0.1	85.5	3.9	5.3	10.5	53.4	172.1
Walpole_MA	6.5	0.0	0.1	1.8	26.5	1.4	2.7	0.6	8.7	48.4
Waltham_MA	397.7	177.6	493.9	72.6	6.3	48.2	42.9	3.1	39.4	1282.0
Watertown_MA	160.7	55.2	240.2	0.0	0.0	2.5	25.1	1.2	3.2	488.1
Wayland_MA	0.0	0.0	4.2	6.6	3.0	5.9	0.2	0.1	4.0	23.9
Wellesley_MA	191.2	0.6	60.9	313.6	20.4	23.9	15.5	4.8	35.3	666.1
Weston_MA	62.0	11.8	9.0	21.9	246.3	63.4	22.9	14.8	89.4	541.6
Westwood_MA	25.5	2.2	2.2	28.9	44.0	10.2	4.2	3.4	12.7	133.3
Wrentham_MA	41.6	65.0	6.3	19.7	70.5	18.7	18.8	4.3	35.9	280.6

Charles River Watershed - Hydrologic Soil Distribution by Community , %							
Community	**HSG A**	**HSG B**	**HSG C**	**HSG C/D**	**HSG D**	**Not Defined**	**Total**
Arlington_MA	0.0%	27.8%	0.1%	0.0%	0.3%	71.8%	100%
Ashland_MA	1.8%	26.3%	54.2%	0.0%	14.0%	3.7%	100%
Bellingham_MA	30.7%	23.6%	17.3%	2.2%	17.6%	8.5%	100%
Belmont_MA	1.3%	32.8%	26.2%	3.0%	10.2%	26.5%	100%
Boston_MA	3.2%	16.6%	7.0%	6.5%	4.1%	62.7%	100%
Brookline_MA	2.0%	20.4%	8.6%	5.4%	4.9%	58.7%	100%
Cambridge_MA	5.1%	12.5%	0.0%	0.0%	0.0%	82.4%	100%
Dedham_MA	15.9%	14.6%	3.0%	21.7%	19.4%	25.4%	100%
Dover_MA	21.0%	26.2%	27.1%	13.3%	11.3%	1.1%	100%
Foxborough_MA	0.8%	7.2%	92.0%	0.0%	0.0%	0.0%	100%
Franklin_MA	20.2%	27.9%	28.5%	3.2%	12.8%	7.5%	100%
Holliston_MA	15.7%	25.1%	28.5%	8.2%	17.7%	4.7%	100%
Hopedale_MA	10.3%	63.0%	11.1%	0.0%	13.6%	2.0%	100%
Hopkinton_MA	0.1%	25.3%	58.0%	7.0%	7.9%	1.8%	100%
Lexington_MA	2.1%	26.2%	12.0%	7.8%	18.7%	33.2%	100%
Lincoln_MA	11.0%	46.9%	12.6%	3.3%	24.8%	1.4%	100%
Medfield_MA	18.5%	31.7%	11.9%	7.6%	24.4%	5.9%	100%
Medway_MA	14.5%	37.3%	31.0%	0.1%	15.2%	1.9%	100%
Mendon_MA	12.3%	71.9%	9.3%	0.0%	6.2%	0.3%	100%
Milford_MA	11.3%	38.3%	17.6%	0.1%	14.3%	18.4%	100%
Millis_MA	25.6%	25.0%	19.3%	0.0%	27.4%	2.5%	100%
Natick_MA	11.9%	17.1%	24.5%	8.5%	13.5%	24.5%	100%
Needham_MA	18.0%	18.1%	11.7%	8.5%	14.0%	29.7%	100%
Newton_MA	7.4%	18.7%	3.1%	2.7%	3.9%	64.0%	100%
Norfolk_MA	34.9%	31.4%	12.8%	2.2%	17.4%	1.3%	100%
Somerville_MA	0.0%	12.9%	0.0%	0.0%	0.0%	87.1%	100%
Sherborn_MA	17.5%	22.0%	33.7%	5.7%	20.4%	0.7%	100%
Walpole_MA	12.4%	28.3%	45.2%	0.2%	13.9%	0.0%	100%
Waltham_MA	2.9%	28.8%	4.5%	5.5%	5.9%	52.5%	100%
Watertown_MA	4.9%	14.7%	3.9%	0.0%	0.0%	76.5%	100%
Wayland_MA	4.8%	54.9%	0.4%	1.0%	9.2%	29.6%	100%
Wellesley_MA	20.3%	18.9%	9.0%	5.1%	4.8%	41.9%	100%
Weston_MA	5.1%	59.9%	10.7%	3.5%	9.9%	10.8%	100%
Westwood_MA	5.5%	25.1%	12.2%	16.8%	15.1%	25.3%	100%
Wrentham_MA	42.4%	26.5%	4.5%	6.0%	10.1%	10.4%	100%
Overall CRW	15.1%	27.3%	16.5%	5.3%	13.1%	22.6%	100%